ANNALS

OF THE

NEW YORK ACADEMY OF SCIENCES

VOLUME XIX

1909

Editor

EDMUND OTIS HOVEY

New York

Published by the Academy

1909

THE NEW YORK ACADEMY OF SCIENCES.

(Lyceum of Natural History, 1817–1876.)

CONTENTS OF VOLUME XIX.

DATES OF PUBLICATION OF AUTHORS' SEPARATES.

			Edition.
(PART I)	ART.	1, pp. 1–40, 31 July, 1909.	175 copies.
	ART.	2, pp. 41–44, 20 April, 1909.	250 copies.
	ART.	3. pp. 45–97, 19 May, 1909.	75 copies.
	ART.	4, pp. 99–119, 31 July, 1909.	125 copies.
	ART.	5, pp. 121–134, 4 December, 1909.	75 copies.
	ART.	6, pp. 135–147, 27 December, 1909.	75 copies.
(PART II)	ART.	7, pp. 149–160, 15 January, 1910.	125 copies.
	ART.	8, pp. 161–204, 1 February, 1910.	300 copies.
	ART.	9, pp. 205–224, 2 March, 1910.	175 copies.
	ART.	10, pp. 225–245, 18 March, 1910.	75 copies.
	ART.	11, pp. 247–282, 21 April, 1910.	375 copies

LIST OF ILLUSTRATIONS.

Plates.

XII.— Scalenohedrons of Calcite parasitic on crystals of Natrolite.
Natrolite and Prehnite supporting sequent Calcite.
A filamentary mineral on a thin coating of Diabantite on trap and supporting parasitic crystals of various minerals.
A filamentary mineral in a cavity between crystals of Datolite and Calcite.

XIII.— Apophyllite and Analcite on Datolite.
Calcite sequent on Stilbite.
Pectolite sequent upon a plate of Prehnite.
Pyrite in prisms and cubes on Heulandite.

XIV.— Succession of Sedimentary Strata in Patagonia and the Pampas Region.

XV.— Tranchée de Forêt.
Grande Couche in l'Espérance.

XVI.— Tranchée de l'Espérance. Nonconformity between the Grande Couche and the overlying dark shales.
Tranchée de l'Espérance. Westerly wall exhibiting irregularity of deposit of Grès Noirs above and gray shales below

XVII.— Tranchée de l'Espérance. Southwesterly corner showing structure of the Grès Noirs group.
Tranchée de l'Espérance. Southerly wall showing faulting in the dark shales.

XVIII.— Glissement de l'Espérance. Southerly wall of l'Espérance.
Tranchée de Longeroux. Recumbent fold in black shales of Grès Noirs.

XIX.— Tranchée de Longeroux. Upper sandstone and black coaly shales of Grès Noirs.
Tranchée de Longeroux. Grande Couche at left; dark shales and folded sandstones of Grès Noirs in background.

XX.— Tranchée de Longeroux. Fault between Grande Couche below and dark shales above.
Tranchée de Longeroux. Glissement de l'Espérance and flexed dark shales.

XXI.— *Acanthoctenus Marshi* F. Cambridge. Epigynum.
Orchestina saltabunda Simon. Male palpus.
Idem. Side view of spider without legs.
Melanophora rufula Banks. Male palpus.
Spermophora meridionalis Hentz. Male palpus.
Theridionexus cavernivolus sp. nov. Male palpus.
Idem. Epigynum.
Alcimosphenus bifurcatus sp. nov Young female.
Micrathena horrida Taczanovsky. Epigynum and lungs.
Idem. Abdomen from above.
Idem. Side view of abdomen.
Micrathena oblonga Taczanovsky. Epigynum.
Idem. Side view of abdomen.
Micrathena sordida Taczanovsky. Epigynum and lungs.
Idem. Side view of abdomen.
Micrathena Vigorsii Perty. Sternum.
Idem. Epigynum and lungs
Idem. Abdomen from behind.
Idem. Side view of abdomen.

XXII.— *Epicadinus tuberculatus* sp. nov. Adult female.
Idem. Epigynum.

Text Figures.

ERRATUM.

Caption of Plate XXIV, instead of "Hoboken, N. Y.," read "Hoboken, N. J."

PLATE I.

BRONZE BUST OF CHARLES DARWIN.

Presented to the American Museum of Natural History
By the New York Academy of Sciences,
12 February, 1909.

[ANNALS N. Y. ACAD. SCI., VOL. XIX, No. 1, Part I, pp. 1–40. 31 July, 1909.]

DARWIN MEMORIAL CELEBRATION.

BY EDMUND OTIS HOVEY,

Recording Secretary.

By invitation of the New York Academy of Sciences, the friends of science in New York City and vicinity gathered at the American Museum of Natural History on Friday, 12 February, 1909, to celebrate the centenary of the birth of the great English naturalist, Charles Robert Darwin, and the semi-centennial anniversary of the publication of his epoch making book "The Origin of Species." In preparation for the celebration, the following circular was sent out, under date of 31 October, 1908, to the members of the Academy and its affiliated societies and other selected addresses.

The investigations and publications of Charles Darwin have had a profound influence upon the progress of science in America as well as in all other parts of the world, but no important memorial of this great naturalist exists in this country. The one hundredth anniversary of Darwin's birth and the fiftieth anniversary of the publication of the "Origin of Species" fall within the year 1909, and the Council of the New York Academy of Sciences proposes that these events be suitably celebrated on Darwin's birthday, 12 February, 1909, when addresses are to be delivered by members of the Academy setting forth Darwin's achievements in different departments of science, and a bronze bust of Darwin is to be unveiled and presented to the American Museum of Natural History by the president of the Academy and accepted by the president of the Museum. It is also proposed to hold in connection with the celebration an exhibition at the Museum of Darwiniana and objects illustrating Darwin's theory of evolution through natural selection and his work in botanical, zoological and geological research

A Darwin Memorial Committee to make all arrangements has been appointed as follows:

E. O. Hovey, *Chairman*	C. F. Cox	W. D. Matthew
J. A. Allen	H. E. Crampton	T. H. Morgan
C. W. Beebe	C. B. Davenport	H. F. Osborn
C. L. Bristol	Bashford Dean	H. H. Rusby
N. L. Britton	A. W. Grabau	W. B. Scott
H. C. Bumpus	W. T. Hornaday	J. J. Stevenson
G. N. Calkins	M. A. Howe	C. W. Townsend
J. McK. Cattell	J. F. Kemp	W. M. Wheeler
F. M. Chapman	F. A. Lucas	E. B. Wilson

The Council considers the coming celebration a fitting occasion for a general expression of appreciation of Darwin's life and work and therefore invites all friends of science in New York and vicinity to join in the proposed commemoration and in erecting a suitable tribute to Darwin's memory in the Natural History Museum, the most appropriate place in this metropolis. * * * * *

EDMUND OTIS HOVEY
Secretary, New York Academy of Sciences
West 77th Street and Central Park, West

CHARLES F. COX
PRESIDENT
New York, 31 October, 1908

The following invitation was sent out to the members of the American Museum of Natural History, the New York Zoological Society, the New York Botanical Garden and sister scientific societies throughout the world, as well as to all classes of members of the Academy and its affiliated societies:

The New York Academy of Sciences

invites you to attend its

exercises commemorating the

One Hundredth Anniversary of the Birth of

Charles Darwin

and the

Fiftieth Anniversary of the Publication of

"The Origin of Species"

American Museum of Natural History

Central Park, West, and Seventy-seventh Street

February the twelfth, nineteen hundred nine

at three o'clock p. m.

On the day of the celebration, the committee charged by the Council with making arrangements for the event carried out the following programme:

Programme

Presentation to the
American Museum of Natural History
of a

Bronze Bust of Darwin

By Charles Finney Cox
President of the New York Academy of Sciences

Acceptance on behalf of
the Trustees of the Museum

By Henry Fairfield Osborn
President of the American Museum of Natural History

Addresses

DARWIN AND GEOLOGY
By John James Stevenson

DARWIN AND BOTANY
By Nathaniel Lord Britton

DARWIN AND ZOOLOGY
By Hermon Carey Bumpus

In the course of the exercises, the Recording Secretary read greetings from several societies, including the following cablegram from Professor Arthur E. Shipley of Christ's College, Cambridge, England:

"Zoologists dining in Darwin's room, Christ's, send greetings to the Academy."

The Committee was assisted in the carrying out of its plans by a special fund of about $1,750.00, the subscribers to which were

Adler, I.
Allis, Edward Phelps, Jr.
Amend, B. J.
Ansbacher, Mrs. A. B.
Arthur, J. C.
Avery, Samuel P.
Baekeland, L. H.
Barron, George D.
Baskerville, Charles
Baugh, Miss M. L.
Beckhard, Martin
Beller, A.
Bessey, Charles E.
van Beuren, F. T.
Bijur, Moses
Birkhahn, Robert C.
Brinsmade, Charles Lyman
Bristol, John I. D.
Britton, N. L.
Brown, Addison
Brown, Edwin H.
Brown, Joseph E.
Bumpus, H. C.
Burgess, T. J. W.
Burroughs, C. W.
Bush, Wendell T.
Chamberlain, Leander T.
Chubb, S. H.
de Coppet, E. J.
Corning, C. R.
Cox, C. F.
Dahlgren, B. E.
Davenport, Charles B.
Davis, William Gilbert
Davis, William T.
Dean, Bashford
De Witt, William G.
Dinkelspiel, Mrs. Pauline Price
Dodge, Cleveland H.
Dodge, Richard E.
Dominick, George F.
Donald, James M.
Doughty, Mrs. Alla
Douglas, James
Dudley, P. H.
Dundas, Ralph Wurts
Dunn, Gano
Dwight, Jonathan, Jr.
Earle, F. S.
Emerson, Miss Julia T.
Emmet, Miss L. F.
Estabrook, A. F.
Field, William B. Osgood
Ford, James B.
de Forest, Robert W.
Frissell, A. S.
Greer, David H.
Godfrey, Charles C.
Goodnow, Henry R.
Goodwin, A. C.
Greenwood, Isaac J.
Gregory, W. K.
Halsted, Byron D.
Hammond, J. B.
Haupt, Louis
Hazard, R. G.
Herrman, Mrs. Esther
Herter, Christian A.
Hess, Selmar
Hewins, Miss Nellie P.
Hills, Alfred K.
Holt, Henry
Hornaday, W. T.
Hovey, E. O.
Howe, H. M.
Hubbard, Walter C.
Huntington, Archer M.
Hutter, Karl
Hyde, Frederic E.
Isaacs, Miss Alice M.
Jones, Dwight A.
Kane, John Innes

Kemp, J. F.
Kennedy, John S.
Kinney, Morris
Klein, Edward N. E.
Kraemer, Henry
Kunz, George F.
Lang, H.
Langeloth, J.
Langmann, G.
Levy, Miss Daisy
Lichtenstein, Paul
Lieb, J. W., Jr.
Loeb, Morris
Lowie, Robert H.
Lusk, Graham
Marble, Manton
Matthew, W. D.
McMillin, Emerson
Meltzer, S. J.
Milburn, John G.
Miller, George N.
Mills, D. O.
Munn, John P.
Nesbit, Abram G.
Oettinger, P. J.
Ogilvie, Miss Ida H.
Osborn, Henry F.
Osborn, William Church
Owens, W. W.
Palm, Charles
Parsons, John E.
Peckham, S. F.
Pedersen, Frederick M.
Petrunkevitch, Alexander
Pfordte, O. F.
Phipps, Henry
Pumpelly, Raphael
Ramsperger, Gustavus
Riederer, Ludwig
Robb, J. Hampden
Rusby, H. H.
Russ, Edward
Sachs, Paul J.
Sauter, Fred.
Schniewind, F.
Scrymser, James A.
Senff, Charles H.
Smith, Mrs. Annie Morrill
Smith, E. E.
Stone, Miss Ellen J.
Strauss, Frederick
Streat, James
Tesla, Nikola
Thaw, Benjamin
Thompson, Miss Anna F.
Thorndike, Edward L.
Thorne, Samuel
Townsend, C. H.
Tuckerman, Alfred
Tweedy, Mrs. A. B.
Van Tassell, F. L.
Walcott, Charles D.
Walker, James
Warburg, Paul M.
Weiss, Mrs. Samuel W.
White, I. C.
Williams, Henry S.
Wilson, Edmund B.
Woodward, R. S.

The Academy gratefully acknowledges the coöperation of the American Museum of Natural History in making the exhibition a success. The exhibition was held from 12 February to 14 March inclusive in the Synoptic Hall (now known as the Darwin Hall) and the Hall of North American Forestry of the Natural History Museum, and it consisted of letters, writings and portraits of Charles Robert Darwin, and exhibits demonstrating various

aspects of the process of evolution of the human species, of other animals and of plants, with special reference to the Darwinian principle of natural selection. The exhibits were assembled and arranged by a subcommittee under the chairmanship of Professor Henry E. Crampton. The following general catalogue of the exhibition indicates its plan and scope.

A

VARIATION UNDER DOMESTICATION

The exhibits demonstrate the results obtained by man with plants and animals which have been under cultivation or domestication for many centuries. Beginning with a single original form, or "species," many different races and types that are stable and breed true from generation to generation have been produced by a process called technically "artificial selection." Domesticated and cultivated forms that vary so as to meet the "artificial" standards of human needs or fancies are kept for breeding purposes, while the less desired individuals are discarded. Sometimes the original progenitor of such races still occurs in a wild form, as in the fowls and pigeons.

Illustrations

1. Races of Indian Corn.
2. Races of Daffodils.
3. Different breeds of domestic fowls, together with their wild ancestor, the Jungle Fowl.
4. Different breeds of pigeons, with their probable common ancestor, the Rock Pigeon.
5. Different breeds of dogs.

B

VARIATION IN NATURE

The exhibits illustrate the universal fact of variation of groups of individuals under natural conditions. The differences between any two individuals may be very slight — the so called "fluctuating variations" — or they may be wider, as in the case of "mutations." The Laws of Variation may be expressed nearly always in precise mathematical form.

Illustrations

1. Races and closely-related species of American Thorn Trees.

2. Fluctuating variations in one species of a clam-like animal, *Tellina.*
3. Slight differences between and among different types of a kind of terrestrial snail, *Helix.*
4. Variable shells of the common scallop, *Pecten,* arranged also to show the general law of variation.
5. Varieties of the Tiger Cowry, from Malaysia.
6. "Mutations," or wide "deviations from type," in several species of birds.

C

STRUGGLE FOR EXISTENCE

The natural rate at which living organisms multiply is so rapid that only a small portion of the individuals which begin life can survive in the struggle for existence. The elimination of the unfit and the survival of only the fit are the results of the many-sided warfare in which all organisms must engage because of over-multiplication. Nevertheless, a form that has been introduced into a new locality may spread with remarkable rapidity, owing to a partial suspension of selection brought about by the exemption of the form from the severe struggle for existence under the conditions of its original habitat.

Illustrations

1. A demonstration of the results of the normal rapid rate of multiplication under the supposition that no elimination takes place -- results which could not be produced in nature.
2. The Water Hyacinth, a plant which has been introduced into Florida, a new habitat, where it has multiplied at such a rate as to choke the streams.
3. A map showing the area of distribution of the English Sparrow in the year 1886, twenty-two years after its introduction into North America.
4. A map showing the spread of the Potato-Bug, during successive decades.
5. A demonstration of the struggle for existence of young plants grown from seeds planted in areas that overlap.
6. Photographs of the conditions in forests, where low-shrubbery is prevented from growing because of the lack of light in the shade of the large trees.
7. A group showing the Meadow-Mouse and its natural enemies and food-organisms; a demonstration of the complexity of the struggle for existence.

D

INSTINCTS

The "mental" operation of lower orders of animals, termed instinctive reactions, are well exemplified by the nest-building habits of birds and insects. The materials employed and the character of the nests display the adaptive nature of the instinctive adjustments to different environmental conditions. The behavior of crustaceans like the Spider-Crab illustrates another peculiar instinctive habit.

Illustrations

1. Nests of various species of birds.
2. Nests of various social insects.
3. A Spider-Crab allowed to decorate itself with various natural objects, so as to be inconspicuous through its resemblance to its surroundings.
4. The death-feigning instinct in Bluebirds.

E

NATURAL SELECTION AND COLORATION

Some striking results of the survival of the fittest are found in the adaptive coloration of several kinds of animals. Many organisms harmonize in color and form with their environment, others mimic natural objects of various kinds, gaining similar protection by such resemblances.

Illustrations

1. The Leaf-Butterflies and other insects, illustrating various kinds of protective resemblances and coloration.
2. Protective resemblance and color-adaptation in the Sargassum-Fish and other lower vertebrates.
3. The uses of color in various species of birds.
4. A group showing the seasonal changes in the coloration of the Ptarmigan.

F

HYBRIDISM

When differing but related forms of animals or plants are crossed, the hybrid offspring may resemble one parent in some features, and the other

parent in different characteristics. Sometimes the hybrid offspring will exhibit "reversion," that is, it will differ from both its parents, and will resemble a remote ancestral form. The laws of inheritance have been much more adequately formulated since the time of Darwin, as in the case of Mendelian inheritance.

Illustrations

1. Specimens of hybrid plants together with their parents.
2. Examples of hybrid fowls.
3. The Darwinian instance of reversion in fowls.
4. The results of hybridization in mammalia.

G

THE FOSSIL RECORD

Following the identification by geologists of the relatively old and the relatively recent layers of rocks, the remains of animals and plants of earlier ages of the earth demonstrate the occurrence at first of simpler organisms, and the successive appearance of more and more complex groups. Sometimes the fossils constitute a comparatively complete series of ancestral species leading to modern kinds, as in the Horse and many invertebrates.

Illustrations

1. A series of specimens of fossil plants showing the succession of their appearance upon the earth.
2. The general succession of invertebrate groups.
3. The evolution of cephalopodous mollusks,—Nautiloid and Ammonitoid types.
4. The evolution of several snail or gasteropod types:
   - *a*) Fulgur series.
   - *b*) Fusus series.
   - *c*) Paludina series.
5. The evolution of Lamp-Shells, or Brachiopods, as exemplified by *Spirifer mucronatus*.
6. Specimens of fossil-bearing rocks showing unmodified and metamorphosed conditions. In the latter case the fossils are destroyed.
7. The evolution of the Horse.
8. The evolution of the Camel.

H

GEOGRAPHICAL DISTRIBUTION

Few organisms occur uniformly throughout the various continental areas of the earth. In general, land types differ more or less widely according to the degree of proximity of the areas where they occur, and their differences are usually regarded as due to their adaptation to the unlike natural conditions of different areas.

Illustrations

1. Specimens of the larger fungi as examples of invariable boreal and tropical plants.
2. The Land Tortoise of the Galapagos Islands, a form which is peculiar to this entirely isolated group of islands.
3. Several kinds of Ground-Squirrels from different localities in the United States.
4. Land Snails from valleys of the Society Islands, in the South Pacific Ocean. Each island possesses characteristic forms, and the different valleys of one and the same island often contain unique forms.

I

PRINCIPLES OF CLASSIFICATION

Resemblances displayed by different species of animals and plants are regarded as indications of common ancestry. It is therefore possible to classify organisms in a tree-like diagrammatic manner, into larger and smaller groups according to their fundamental similarities. The principle seems to be universal for all plants and all animals.

Illustrations

1. Living specimens of Cactus plants.
2. A typical series of Crustacea.

J

PRINCIPLES OF HOMOLOGY

Parts of organisms presenting the same fundamental plan of construction, though they differ in function, are spoken of as "homologous."

Illustrations

1. Mammalian limbs adapted for use in various ways, though they exhibit the same kind of skeletal framework.
2. Specimens illustrating the different forms of leaves of the ferns and their relatives.

K

PRINCIPLES OF EMBRYOLOGY

When an animal develops, it passes gradually from its early stages with their simple construction to the progressively complex stages of later and adult life. During this process, it closely resembles in an embryonic condition an adult organism of a lower order. The general principle of development is that an embryonic series of stages exhibited by any animal is a brief review or recapitulation of the ancestral history of its kind.

Illustrations

1. Models and specimens displaying the gill-slits of chick embryos, and their correspondence with the gill-slits of fishes.
2. Models showing the blood-vessels and the hearts of different classes of vertebrates, and some of the corresponding embryonic stages in the development of the heart in man.
3. Preparations showing the occurrence in a chick embryo of a primitive body-support, the notochord, which occurs in the adult in *Amphioxus*, a primitive relative of the vertebrates, and in vertebrates.
4. Models showing the development of the human brain, and its resemblance at various stages to the adult brains of lower mammalia.
5. The third eye or pineal body of an adult lizard, and the corresponding vestige in the embryonic human brain.

L

RUDIMENTARY AND VESTIGIAL ORGANS

Vestigial organs are remnants of once-useful parts, that have undergone regressive evolution. Rudimentary structures often occur in some forms, while in related species they reach a far higher degree of development.

Illustrations

1. A Prickly-pear Cactus and a New Zealand Bramble showing reduced leaves.
2. Insects exhibiting rudimentary and vestigial organs.

M

INSECT-EATING PLANTS AND CLIMBING PLANTS

These plants display two different kinds of adaptations — one in respect to nutrition and the other in respect to the development of structures to afford support.

N

FERTILIZATION IN PLANTS

The exhibit demonstrates the peculiar nature of the process of fertilization, and the special mechanisms that these organisms have developed to bring about fertilization in various ways. The processes are adjusted intimately to the visits made by insects to flowers for nourishment.

O

THE DESCENT OF MAN

The general principles of evolution hold true for the attainment by the human species of its present place in nature. The exhibits demonstrate in a general manner the various stages reached by organisms nearly related to man, which the human species has surpassed.

Illustrations

1. A series of primate animals from the Lemurs to Man.
2. A series of crania of primate mammals, showing the gradual enlargement of the brain case and the relative reduction of the jaws.
3. A series of casts and models of the brains of various primates, showing the progressive evolution of the brain, and especially of the cerebrum.

DARWINIANA

Loaned by Mr. Charles F. Cox.

1. Page from original manuscript of "Descent of Man." Text of part of Page 309, Chapter VIII, Volume I. 1st edition, 1871.
2. Page from original manuscript of "Descent of Man." Text of part of Page 183, Chapter V, Volume I. 1st edition, 1871.
3. Two pages from the original manuscript of "Descent of Man." Text of part of Pages 42–43, Chapter II, Volume I. 1st edition, 1871.
4. Page from the personal journal of Charles Darwin, kept while on the "*Beagle* Voyage," 1831–1836.
5. Sixteen autograph letters. Miscellaneous.
6. Complete collection of letters to W. B. Tegetmeier, 1855–1880.
7. Letters to Albany Hancock, 1849–1854. (Concerning the discovery of the parasitical or complemental male Cirripedes.)

Books

8. Researches in Natural History. 1st edition, 1839.
9. Researches in Natural History and Geology. 2nd edition, 1845. 2 copies.
10. Zoölogy of the Voyage of H. M. S. Beagle. Edited by Charles Darwin. London, 1840. 3 vols.
11. Structure and Distribution of Coral Reefs. 1st edition, 1842.
12. The Structure of Coral Reefs. 2nd edition, 1874.
13. Observations on Volcanic Islands. 1st edition, 1844.
14. Observations on Coral Islands. 2nd edition, 1876.
15. Coral Reefs, Volcanic Islands, South America. United edition, 1851.
16. Geological Observations on South America. 1st edition, 1846.
17. Monograph on the Cirripedia,— Lepadidæ. 1st edition, 1851.
18. Monograph on the Cirripedia,— Balanidæ. 1st edition, 1854.
19. Fossil Lepadidæ and Balanidæ. 1st edition, 1851–1854.
20. "The Origin of Species." One of the 1250 copies of the 1st edition, November 24, 1859.
21. On the Origin of Species. 1st edition, 1859.
22. On the Origin of Species. 2nd edition, 1860. 2 copies.
23. On the Origin of Species. 3rd edition, 1861.
24. On the Origin of Species. 4th edition, 1866.
25. On the Origin of Species. 5th edition, 1869.
26. On the Origin of Species. 6th edition, 1882.

27. Naturalist's Voyage Round the World. 1st edition, 1860.
28. The Fertilization of Orchids. 1st edition, 1862.
29. The Fertilization of Orchids. 2nd edition, 1877.
30. On the Movements and Habits of Climbing Plants. 1st edition, 1865.
31. On the Movements and Habits of Climbing Plants. 2nd edition, 1875. 2 copies.
32. Animals and Plants under Domestication. 1st edition, 1868. 2 vols.
33. Animals and Plants under Domestication. 2nd edition, 1875. 2 vols.
34. The Descent of Man. 1st edition, 1871. 2 vols. 3 copies.
35. The Descent of Man. 2nd edition, 1874. 2 copies.
36. On the Expression of the Emotions. 1st edition, 1872.
37. On Insectivorous Plants. 1st edition, 1875.
38. Cross and Self Fertilization of Plants. 1st edition, 1876.
39. Cross and Self Fertilization of Plants. 2nd edition, 1888.
40. The Different Forms of Flowers. 1st edition, 1877.
41. The Movements of Plants. By Charles and Francis Darwin. 1st edition, 1880.
42. Vegetable Mould and Earth-worms. 1st edition, 1881.
43. Vegetable Mould and Earth-worms. 1882.

WORKS TO WHICH CHARLES DARWIN CONTRIBUTED OR WHICH CONTAIN WRITINGS OF HIS NOT ELSEWHERE PUBLISHED.

44. Voyages of the Adventure and the Beagle. 3 vols. & appendix. London, 1839. Volume III by Charles Darwin.
45. The Admiralty Manual of Scientific Enquiry. London, 1849. "Geology" by Charles Darwin.
46. Flowers and their Unbidden Guests. By Kerner. London, 1878. Prefatory letter by Charles Darwin.
47. Life of Erasmus Darwin. London, 1879. Prefatory notice by C. Darwin.
48. Prehistoric Europe. By James Geikie. London, 1881. Quotes letters from Charles Darwin on Southampton gravels.
49. Studies in the Theory of Descent. By Weismann. London, 1882. Prefatory note by Charles Darwin.
50. The Fertilization of Flowers. By Müller. London, 1883. Preface by Charles Darwin.
51. Mental Evolution in Animals. By Romanes. New York, 1884. Posthumous essay on "Instinct" by Charles Darwin.
52. Darwinism. By Alfred Russel Wallace. London, 1889.
53. "Miscellaneous and Hitherto Uncollected Writings of Charles Darwin." Compiled by C. F. Cox, New York, 1904.

54. "Life and Letters of Charles Darwin." Edited by his son Francis Darwin. Original edition, 1886. Extra-illustrated with more than 400 portraits, autograph letters, etc.
55. "More Letters of Charles Darwin." Edited by his son Francis Darwin. Original edition, 1903. Extra-illustrated with about 200 portraits.
56. "Pedigree of the Family of Darwin." Compiled by H. Burke, Esq., F. S. A., 1888.
57. Catalogue of the Library of Charles Darwin, now in the Botany School, Cambridge.
58. Portrait. Photograph from life by Maull & Fox, about 1854, print from recently restored negative.
59. Portrait. Photograph from life by Maull & Fox, about 1854. Print from recently restored negative.
60. Portrait. Proof of wood-engraving, made in 1889 by G. Kruell, after photograph made from life by Maull & Fox, about 1854.
61. Portrait. Woodcut from "Harper's Magazine" of October, 1884, after photograph from life by Maull & Fox, about 1854.
62. Portrait. Photograph from life by Mrs. Cameron, 1868.
63. Portrait. Engraving on steel by C. H. Jeens, published in "Nature," June 4, 1874, from photograph from life by O. J. Rejlander, about 1870.
64. Portrait. Woodcut from "London Graphic" of July 29, 1882, after photograph from life by O. G. Rejlander, about 1870.
65. Portrait. Proof of wood-cut from "Century Magazine" of January, 1883, after photograph by Capt. Darwin, about 1874.
66. Portraits. Two copies (one loaned by President H. F. Osborn) of proof etching by G. Mercier, published 1890, after the painting made from life in 1875 by W. Ouless, R. A.
67. Portrait. Woodbury-type from photograph from life by Lock & Whitfield. Published in "Men of Mark" by Sampson, Low & Co., 1876.
68. Portrait. Proof etching by Leopold Flameng, published 1883, after painting from life by Hon. John Collier, made for the Linnæan Society in 1881.
69. Portrait. Proof wood-engraving, made in 1889 by G. Kruell, after a photograph made from life by Elliott & Fry, 1881.
70. Portraits. Three photographs from life, by Elliott & Fry, 1881.
71. Portrait. Engraving by S. Hollyer, after photograph from life by Elliott & Fry, 1881.
72. Portrait. (Property of H. F. Osborn.)

73. Portraits of Darwin's contemporaries. Eighty transparencies.
74. Interior of Darwin's Library. (Property of H. F. Osborn.)

The exercises of the afternoon were held around the bust as a center. The President of the Academy, Mr. Charles F. Cox, called the meeting to order at about a quarter after three o'clock and delivered the following address:

THE INDIVIDUALITY OF CHARLES DARWIN.

By Charles F. Cox.

We are assembled, at the invitation of an organization devoted to the dissemination of scientific knowledge, under the hospitable roof of an institution maintained for the promotion of systematic observation, for the purpose of honoring the memory of one of the greatest of seers. Charles Darwin, whose birthday we celebrate, was a man of the clearest mental vision born into a generation scientifically blind. He first, of those in his day accounted wise, was able to see all nature unfolding according to uniform and verifiable law. The outlook of other men called by his contemporaries scientists and philosophers was, as a rule, limited and obscured by a narrowing and hampering doctrine of supernatural intervention. It is hard for us, who are privileged to contemplate with admiring minds the harmonious interrelations of all natural phenomena, to realize that only fifty years ago it was commonly regarded as both irrational and immoral to believe that one great principle underlay the origin, maintenance, diversification and development of living forms and that that principle was discoverable through human investigation. During the ages previous to the memorable year 1859 a few bold thinkers, now and then, had ventured to suggest a theory of general evolution, but they had failed to supply it with a substantial foundation of proof, or to assign to it a reasonable and intelligible cause, and had been, consequently, one and all, overwhelmed and suppressed by the powerful and prevalent dogma of special creation. Naturalists had been for centuries active in the collection of facts, but, until Darwin came, the various attributes and activities of living things remained disconnected and unexplained. Indeed, it was impossible that they should have been correlated and elucidated as long as the domain of science was in thralldom to tyrannical authority and originality of thought was little less than a crime. For a hundred years prior to Darwin even professed students of nature were not free to see what lay under their very eyes. The scientific

world was awaiting a liberator. Finally the revolution was proclaimed and the first decisive blow struck by the publication of "The Origin of Species" on the twenty-fourth of November, 1859. It was no hasty and ill-considered stroke. Events had been shaping themselves to this end since the twenty-seventh of December, 1831, when the little brig *Beagle* sailed from Plymouth harbor, bearing the unknown and youthful Charles Darwin to the discovery of a new world — not, however, an unexplored continent to be claimed for commerce and civilization, but a vastly greater and more valuable realm of thought to be opened to knowledge and conquered for intellectual freedom. Darwin, like the prophets of old, in preparation for his exalted mission, betook himself to the uninhabited wilderness, away from the domination of other minds, in order that he might draw inspiration from untrammeled and clarifying communion with nature. In his narrow cabin on the broad Atlantic, on the desert plains of Patagonia, on desolate and unpeopled islands of the Pacific, in the dark and solemn forests of the tropics, and on the summits of the bleak and barren Andes he gained the coveted prize of wisdom which had been denied him in the populous halls of two great universities, where his free spirit had rebelled against the rigid conventionality of classical education.

Although a born investigator, he had been driven and harassed for fourteen years by unthinking instructors devoid of both the ability and the disposition to consider his natural endowments and inclinations and who, with one or two exceptions, according to his own later judgment, wasted their time upon an unappreciative and discouraging pupil. He says of himself that he was slow in learning, but a review of his productive life clearly shows that, if he was dull in any respect, it was solely in the matter of accepting ideas at second hand. It happened, merely, that what most of his teachers were prepared to impart he was not constituted to receive; and so one of the acutest observers the world has ever known was thought to be inattentive and unreceptive. During all the school days of his childhood, passed in his native town of Shrewsbury, not only were his superb mental gifts wholly unrecognized, but no attempt was ever made to find out if he had any such gifts. He spent seven useless years at Dr. Butler's so-called "great school," but, apparently, the head master never came to know his talented pupil, for the educational system which prevailed in that institution had no reference to "the discovery of the exceptional man." The one ceaseless effort of his schoolmasters was to crowd him into the common mold.

Receiving no sympathy and little assistance from those who should have been the guides and advisers of his boyhood, he developed "a strong taste for long solitary walks" and cultivated the habit of stealing time for more or less surreptitious collecting in several departments of natural history.

Thus he became, in all important respects, self-taught and, driven to his own resources, his natural inclination to consider his path of life as lying far aside from the common highway was confirmed and strengthened. This sense of solitariness followed him to the end of his life and was, no doubt, an important factor in the formation and preservation of his extraordinary individuality and faith in his own powers. Darwin's followers may therefore bless even the obtuseness and shortsightedness of his preceptors who failed to spoil him by their unwise treatment.

When, in 1825, Doctor Robert Darwin concluded that his son Charles was lacking in natural aptitude for scholarship, he sent him to Edinburgh University, intending that he should follow in the footsteps of his father and of his grandfather by becoming a physician. But here, again, the young man found himself unable to receive what was offered him on the strength of ancient authority. The instruction dispensed in that hoary institution was, to him, perfunctory and uninspiring and he was once more forced to seek the real enlargement of his knowledge by self-directed methods. In this way he appears to have obtained, at Edinburgh, some sort of acquaintance with the fundamental principles of scientific research, but, as the learning thus acquired was not in the line of his intended profession, it was not appreciated by his family and friends. Accordingly, after two sessions spent at that university, it was decided that his regular studies had been entirely misdirected and he was therefore withdrawn and sent to Cambridge. There he was still worse misguided in the endeavor to educate him in theology. Again was repeated the old story of an uncongenial curriculum ostensibly conformed to but in reality shirked and avoided in favor of natural history privately followed by side paths. The unwilling student wished to be obedient to his father's direction, but native bent proved stronger than conventional rule — the call of destiny louder than the voice of filial duty.

His father, in most things a wise man, saw in his son's insect- and bird-hunting proclivity a tendency to the life of "an idle sporting man" and was sorely grieved and disappointed when he was obliged to concede the failure of his plan to connect the house of Darwin with the Church of England. Fortunately, however, the troublesome student came under the influence, at Cambridge, of a teacher endowed with more than ordinary discernment and, in this particular matter, with somewhat unusual independence and courage and he took the budding naturalist and his lawless pursuits under his patronage and protection. To the faith and friendship of Professor J. S. Henslow Darwin was indebted for his appointment to the *Beagle* expedition, and to Professor Henslow, who robbed the church to enrich science, the world owes an incalculable debt of gratitude for the discovery, if not for the development, of one of its loftiest geniuses.

Others besides Henslow, however, contributed to the fixation of Darwin's inborn talents and abilities, but Darwin never admitted that he received, either at Edinburgh or at Cambridge, any thing like systematic mental training. He was, from the beginning of his school days to the end of his university life, a person set apart for individual preparation for a special and peculiar career. When he bade farewell to Christ's College, Cambridge, in the summer of 1831, his actual education was yet to be acquired, but not through human instruction. He has himself declared: "I have always felt that I owe to the voyage the first real training or education of my mind."

It was therefore no professional scientist who eagerly accepted the unsalaried post of naturalist to the *Beagle* expedition around the world, but a modest, though confident, youth of twenty-two whose most important article of outfit was the first volume of the first edition of Lyell's "Principles of Geology," which had been published the year before, the second volume of which was not issued until after Darwin had reached South America. Thus it was providentially ordered that during the formative period covered by this epoch-making voyage, Darwin should remain as free as possible from human influences. If, instead of proceeding, raw as he was, directly from the seclusion of the university to the isolation of the voyage, he had directed his steps to the metropolis and had there mingled with the leaders in scientific thought, it is quite possible, if not probable, that he would have fallen under their authority and would have accepted the orthodox beliefs of his time. If that had been the case, we might be dominated to-day by the prohibitive doctrine of the immutability of species, instead of enjoying that freedom of thought and liberty of investigation to which Darwin made us heirs. But, happily for the intellectual world, during the five years which Darwin spent on the *Beagle*, under the intimate tutelage of mother nature, he laid, for our benefit, as well as for his own, the solid foundations of his never failing habit of mind in which open-eyed teachableness ever supplemented unwavering honesty of purpose and fearlessness of approach.

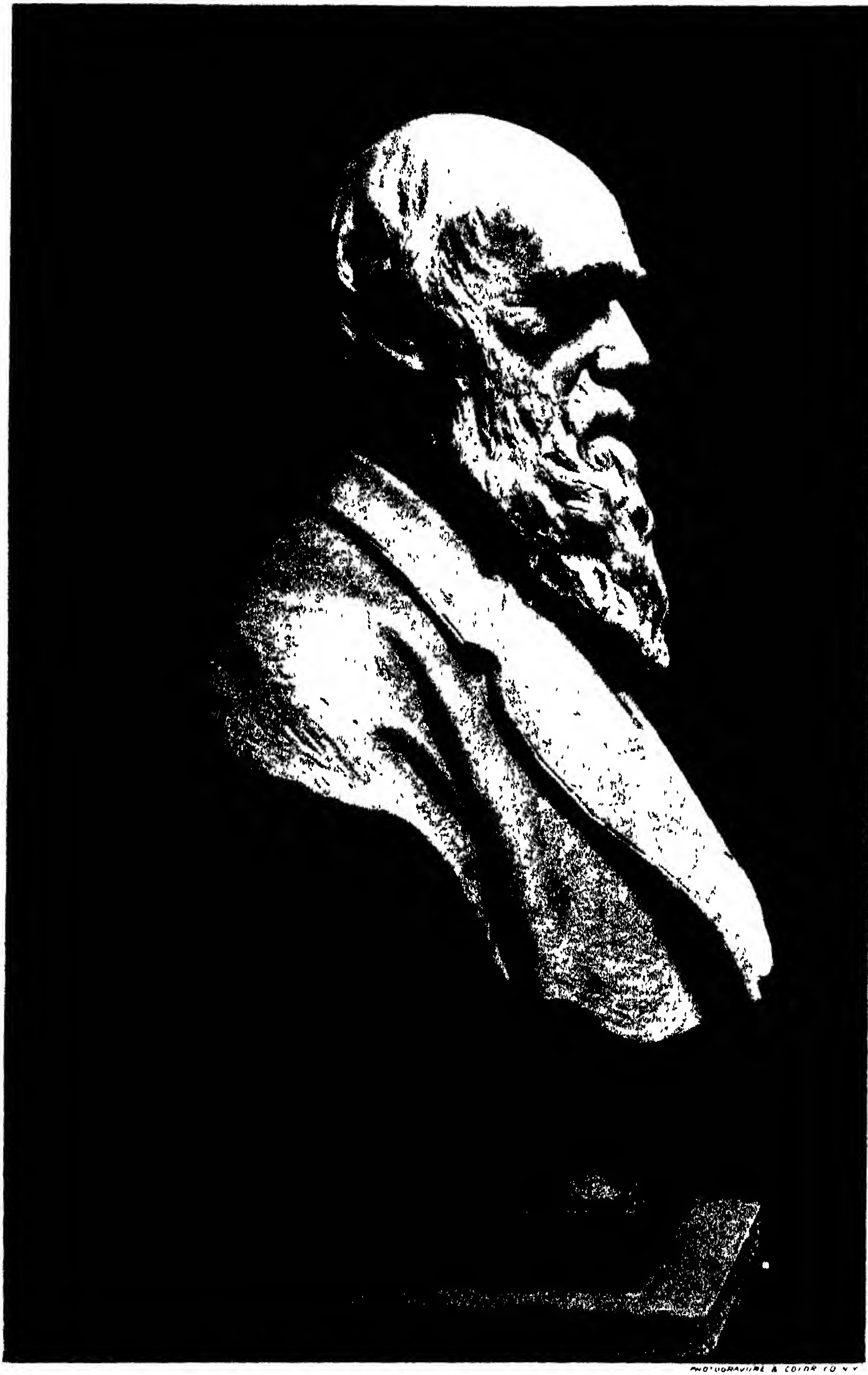
After Darwin's return from the circumnavigation of the globe, he resided, for a little more than five years, in London, and that was the only portion of his life during which he was in actual personal contact with any considerable number of his fellowmen. Even then, however, he was mostly engaged with his own thoughts, for he was arranging his collections and preparing for publication the results of his observations made while on the *Beagle* voyage. It was at the very beginning of this residence in London (July, 1837), while the things he had seen in South America and the Pacific Islands were still fresh in his memory that he opened his first note-book

for facts in relation to the origin of species, about which he says he "had long reflected." For twenty-two years thereafter Mr. Darwin continued to pursue this revolutionizing subject with unexampled patience and, except as to two or three intimate friends, entirely within the privacy of his own mind.

In September, 1842, he went into retirement at Down, an out-of-the-way village in Kent. There, partly compelled by ill-health, he dwelt as a recluse for forty years, serenely contemplating nature and diligently gathering information, but seldom emerging into the world from which his richly-stored and phenomenally creative intellect had little to gain but to which it never ceased to give, during the remainder of his life. Bare knowledge he welcomed from any source, but opinions and deductions he invariably produced for himself. What he wrote to H. W. Bates, who complained of a want of advice is true of Darwin himself: "Part of your great originality of views," he said, "may be due to the necessity of self-exertion of thought." What has been said by his son Francis is equally true of Mr. Darwin — one of his most striking characteristics was "that supreme power of seeing and thinking what the rest of the world had overlooked."

Mr. Darwin was what we are accustomed to call a genius, but I know of no good definition of a genius but *a man of insight*. The person who by his natural acuteness of perception is able to see into and through problems which to other men are baffling or insoluble, has the highest right to be considered inspired. Darwin's wonderful endowment in this respect constituted him, by divine right, a leader of men. The world has always justly honored its standard bearers and we are here to pay homage to the name of one of the most attractive and commanding of them all. In other parts of this city and of this land, our fellow-citizens are gathering to-day to pay grateful tribute to the estimable character, and to recall the memorable deeds of a great emancipator. We likewise are celebrating the beneficent acts of a man, simple and modest as that other, who, at a critical period, spoke courageous words which conferred freedom on millions of his fellow creatures. It is altogether fitting that the birthdays of these two benefactors should be the same.

We now dedicate this monument, in this appropriate place, not only to the honor and memory of Charles Darwin the great thinker, whose life and personality we admire, but also to the encouragement and guidance of all who may hereafter frequent these halls — as a testimony to the power of self-reliance and independence of mind which Charles Darwin preëminently exemplified and illustrated. May this portrait of a noble truth-seeker which we now unveil, signify, for all time to come, to him who would advance the boundaries of scientific knowledge, that nature will yield up her secrets only when appealed to directly and in humility and purity of spirit.



PHOTOGRAVURE & COLOR CO. N.Y.

Plate II.

THE ACADEMY BUST OF DARWIN.

Right side of the model.

At the close of his address, President Cox gave the signal for unveiling the bust,[1] and turning to President Henry Fairfield Osborn said

President Osborn:

On behalf of the New York Academy of Sciences, I have the honor of presenting this bust to the American Museum of Natural History and of asking your acceptance of it, in the hope that it may stand in this place for many generations to come as evidence of the high esteem in which the life and work of Charles Darwin are held by the men of science of this country, and also as a token of the cordial relations existing between the Academy of Sciences and the Museum of Natural History, which you yourself have done much to establish and promote.

In response to the address of President Cox and the presentation of the bust, President Osborn replied as follows:

ACCEPTANCE OF THE PORTRAIT OF DARWIN.

By Henry Fairfield Osborn,

President of the American Museum of Natural History.

The bronze bust of Charles Darwin presented by the New York Academy of Sciences is accepted by the Trustees of the American Museum of Natural History with a three-fold meaning.

First, as a noble work of art conveying in its fidelity of portraiture a striking likeness of the great naturalist, with the far-seeing vision of his deep-set eyes controlled by a great brain in which the powers of observation and of reason were developed far beyond the average. Personal recollection of Darwin's face and head strengthens the first impression that this latest work of William Couper will be welcomed by naturalists everywhere as a singularly grand and impressive likeness.

The second reason why this gift is welcome is that it memorializes in a manner most grateful to the Trustees and Scientific Staff of this Museum that the scientific men of New York appreciate the work that is being carried on here for the promotion of natural science, that the combination of muni-

[1] The bust is of bronze, of heroic size, and is mounted upon a pedestal of polished gneissoid granite from Stony Creek, Connecticut. The bust was prepared expressly for the Academy by the New York sculptor William Couper from photographs and other data. The portrait represents the naturalist in the full maturity of his powers and rather past middle life.

cipal and private munificence with the ardor of exploration and research and devotion to public scientific education for which this institution stands meets the approval and support of the members of the New York Academy of Sciences, the oldest and most dignified of all the scientific associations in this great city. This gift will encourage the Museum to renewed efforts both in the sphere of pure science and in the sphere of popular education.

Finally the gift is welcome because it permanently associates the name of the great naturalist with the Museum and especially with one of our newer exhibition halls, which is especially devoted to the exposition of the great general phenomena of biology, as seen in the structure, the embryonic development, the adaptness in color and form, the marvelous diversity but yet unity of the animal world, to the true interpretation of which Charles Darwin devoted his life.

Further to cement the name and spirit of Darwin with the exhibition in the midst of which this splendid portrait will be placed, it gives me great pleasure to announce that the Trustees have unanimously voted to name this hall after the illustrious naturalist, "Darwin Hall," and have prepared and placed here on this centennial day two bronze tablets which will be a permanent record of the time and place of this dedication.

At the close of President Osborn's address the following addresses were delivered, setting forth Darwin's relations to the three subdivisions of natural science — geology, botany and zoology — in pursuit of which he expended his great energies.

DARWIN AND GEOLOGY.

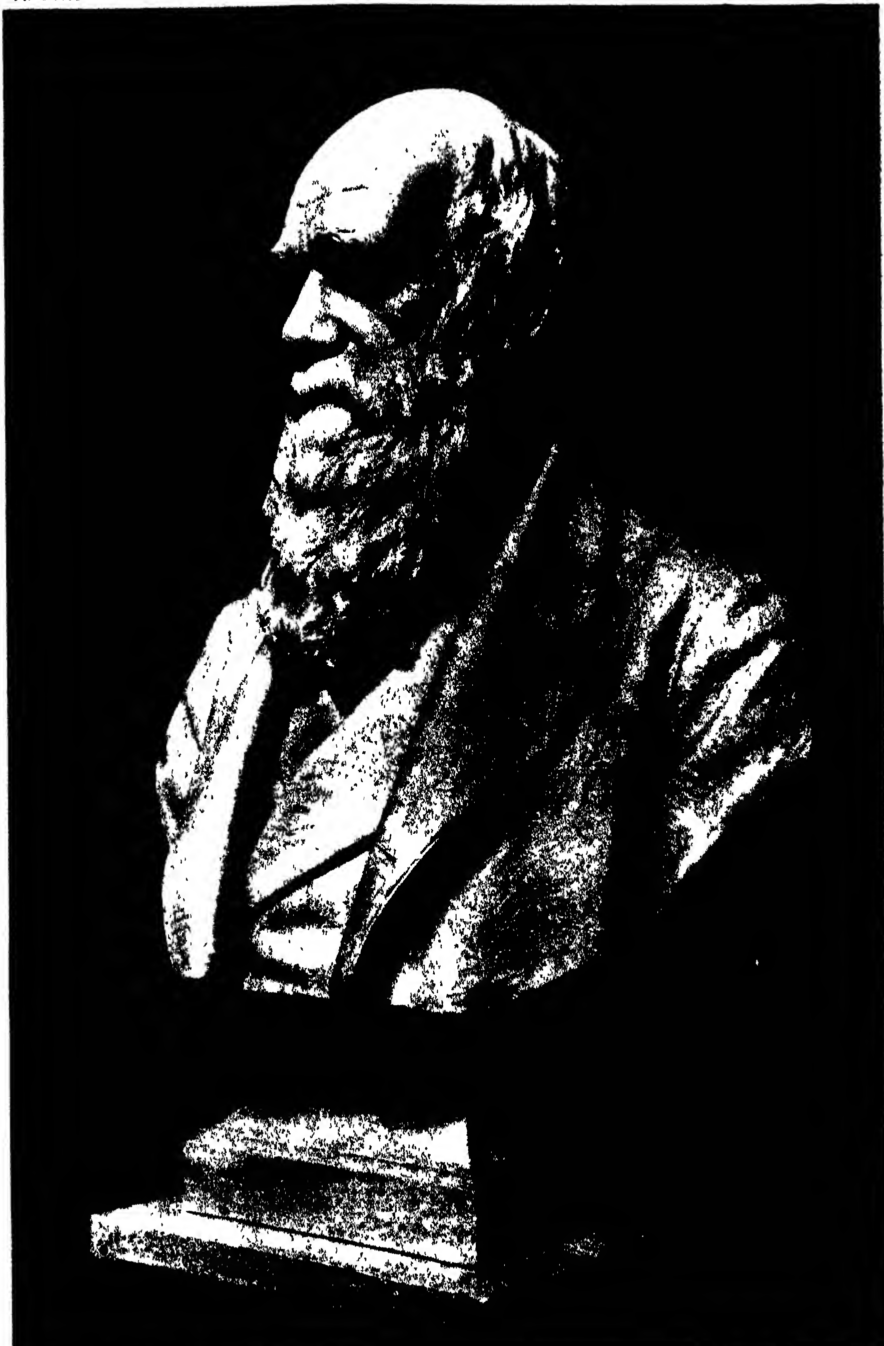
By Professor John James Stevenson.

Charles Darwin was born in a time of intellectual unrest. Explorers, students of chemistry and workers in mines had been adding to actual knowledge for nearly one third of a century and thoughtful men had been forced to recognize the worthlessness of many conceptions which had long passed current. Nowhere was this unrest more manifest than among the younger geologists; but they were compelled to express themselves cautiously for, fettered by a false chronology, the church dignitaries who controlled the universities rebuked investigation and branded as infidels those who recorded obnoxious facts. Little more than a year prior to Darwin's birth, the Geological Society of London had been founded as a protest against subjective study of this globe, but already many adherents to the principles

Plate III.

THE ACADEMY BUST OF DARWIN.

Left side of the model.



of that society had appeared on the continent, proclaiming that actual knowledge of conditions must precede attempts to explain them.

The development of opinion was so rapid that before Darwin reached his majority the geological pendulum had made its great swing from the doctrine of cataclysms to that of uniformity; from the belief that this globe is less than 6,000 years old to an abiding faith that its age cannot be measured in years. It was amid such conditions that, toward the close of his university studies, he came under the influence of Henslow and Sedgwick, the latter being engaged at that time along with Murchison in an effort to unravel the tangle of Welsh geology. Some have said that these men taught him how to observe; not so, he was already a keen observer, and they merely led him into wider fields.

In 1831, Captain Fitzroy was assigned to command H. M. S. *Beagle*, a little brig of 240 tons, and was commissioned to complete the coast survey of southern South America as well as to run a line around the globe. When he expressed the wish to be accompanied by a naturalist, Darwin, then only twenty-two years old, promptly volunteered his services, which were accepted, and he was enrolled as a supernumerary member of the staff. The *Beagle* left England on December 27, 1831, and returned on October 2, 1836, bringing with it Charles Darwin, now grown intellectually to man's stature and bearing a notable cargo of material collections, as well as of accumulated observations. There was no haste in publication; aside from some very brief communications to societies, nothing appeared until 1839, when the *Journal of Researches* was printed. Owen's descriptions of the fossil mammalia were issued in 1840, with an introduction by Darwin, and the final publication of results was made in three parts, dated 1842, 1844, and 1846. Thus early in his career, Darwin showed that caution which characterized him throughout life, an indifference to priority which was the outgrowth of his love of accuracy.

Part 2 of the "Geological Observations," dated 1844, relates chiefly to volcanic islands. In most cases the stay at those was brief and the studies were fragmentary; yet Darwin saw enough to let him discuss the origin of volcanic cones, to determine some cardinal points respecting the distribution of the islands, to distinguish submarine from subaërial lava flows and to prove that experimental studies on metamorphosis of limestones had led to very nearly true conceptions of the process.

As the coast survey of southern South America was the important object of Captain Fitzroy's expedition, there was ample time for a good reconnaissance of that region and Darwin spent nearly six months in studying the pampas from the Parana and Uraguay rivers southward almost to Magellan's Strait. A synopsis was given as an introduction to Owen's memoir, but the

details did not appear until 1846, when they were published as Part 3 of the "Geological Observations." The whole subject was discussed attractively in the second edition of the *Journal of Researches.*

The superficial deposit of the great plains is a "reddish argillaceous earth," containing concretions of indurated marl, which at times become continuous layers or even replace much of the red earth. In the northerly part of the plains area, this pampas deposit, which passes downward into sands, limestones and clays of late Tertiary age, yielded no marine shells to Darwin; its infusoria, studied by Ehrenberg, proved to be partly marine, partly freshwater, while the marly concretions resemble some freshwater limestones seen in Europe; but this paucity of invertebrate life was unimportant, for the whole of that region proved to be one vast cemetery, in which the skeletons of gigantic extinct mammals are so numerous that a line could not be drawn in any direction without passing through some bones. In northern Patagonia the red deposit is bound closely to an overlying gravel, containing marine forms belonging to species now existing on the coast, while in southern Patagonia marine shells occur in the pampas deposit itself.

Darwin believed that this pampas material was deposited within a vast estuary, into which great rivers carried from the surrounding region carcasses of the animals whose skeletons were entombed in muds tranquilly accumulating on the bottom. All conditions go to show that the mammalia became extinct after the sea had received its present fauna, and there is nothing to suggest that a period of overwhelming violence swept away and destroyed the inhabitants of the land; everything supports the contrary belief. The only noteworthy change in conditions has been a gradual elevation of the continent; but that was not enough to modify the climate or to bring about a change in the land fauna.

Several of the important genera collected by Darwin had been found in North America long prior to his time. This similarity of the Quaternary faunas induced him to speculate on the causes which had divided the American continent into two well-defined and somewhat contrasting zoölogical provinces. He does not hesitate to suggest recent elevation of the Mexican platform or, more probably, recent submergence of the West Indian Archipelago as a conceivable cause of this separation. It seems to him most probable that the elephants, the mastodons, the horses and the hollow-horned ruminants of North America "migrated, on land since submerged near Bering Straits, from Siberia into North America, and thence, on land since submerged in the West Indies, into South America, where for a time they mingled with forms characteristic of that southern continent and have since become extinct." Had this American Museum of Natural History existed in Darwin's day, study of the remarkable exhibits in its Mammal

Hall would have enabled him to extend his list of extinct forms common to both continents; and possibly he might have anticipated some of the all-important generalizations for which the world is indebted to the former president of this academy who now is president of the museum.

Nothing in South America, east or west, escaped Darwin; from glaciers to peat bogs, from earthquakes to climatal variations, everything was important; but what impressed him most on both sides of the continent were the evidences of extremely slow secular movement in the earth's crust. This was the preparation for that study of the coral islands which resulted in his chief contribution to philosophical geology.

Many voyagers prior to 1833 had observed and had tried to account for the strange atolls, or low ring like coral reefs, each inclosing a lagoon which communicates with the sea by a narrow channel; but Darwin discovered other forms of reefs which were equally perplexing. Many islets of rock are fringed by coral growth, while vast barrier reefs, separated from the land by channels of varying depth, extend at times for hundreds of miles along coasts. All explanations by previous observers were defective, as they seemed to ignore these types as well as other features, not less important.

Reef-making corals can not endure exposure to the air and they can not thrive at a depth of more than 20 fathoms, so that their vertical range is about 115 feet; yet hooks and anchors brought up coral rock and sand from many hundreds of feet below the limit of growth; in a great number of instances, the atolls or ring-like reefs are mere peaks rising with abrupt slopes from "fathomless" abysses. Coral-bearing areas within the Indian and Pacific Oceans are of vast extent, there being chains of archipelagos 1,000 to 1,500 miles long. The reefs are rudely circular or elliptical in the islands, but are linear along the coasts; in the one case, the reef incloses a lagoon, in the other, a lagoon-like channel separates the reef from the coast. These are fundamental elements of the problem, not one of which may be neglected in the solution. A clue to the explanation was found by this keen observer, when he saw an islet of old rock, fringed with coral, rising from the lagoon of an atoll, so that the atoll-ring resembled in many respects the barrier reef of a continent and the lagoon itself resembled the lagoon-like channel seen on the Australian and other coasts.

Chamisso's suggestion that coral reefs had been formed on banks of sedimentary material seemed wholly incompetent to meet the conditions, for the areas are too vast, and Darwin was compelled to believe that the atolls rest on rocky bases; but even on this supposition, it appears incredible that peaks of several great mountain chains should all come to within less than 180 feet of the surface and that not one rose any higher. The long study in South America had prepared him to seek an explanation in mobility

of the earth's crust; but it was clear that elevation could not bring about the conditions, as that would destroy the corals themselves; subsidence alone can account for the phenomena. And thus Darwin presents his case:

> If then the foundations of the many atolls were not uplifted into the requisite position, they must of necessity have subsided into it; and this at once solves every difficulty, for we may safely infer from the facts given in the last chapter, that during a subsidence the corals would be favorably circumstanced for building up their solid framework and reaching the surface, as island after island slowly disappeared. Thus areas of immense extent in the central and most profound parts of the oceans might become interspersed with coral islets, none of which would rise to greater height than that attained by detritus heaped up by the sea, and nevertheless they might all have been formed by corals which absolutely require for their growth a solid foundation within a few fathoms of the surface. . . . The rocky bases slowly and successively sank beneath the level of the sea, while corals continued to grow upward.

The origin of the ring as well as that of the barrier reef seemed to be easily explained by this hypothesis. The corals on the outer side of the reef grew with greater rapidity than did those within, as the supply of food is constant; those on the inner side became starved and eventually the interior growth ceased, and the lagoon was shallowed by wind-drifted material from the shores.

Darwin's hypothesis and the facts on which it was based have become so familiar that students sometimes express surprise that so much praise has been awarded to the author. The conditions as presented in his discussion are so clear that certainly no man could reach any other conclusion. That is true, but it is true only because Darwin marshalled his facts in a manner so masterly; in any event, it is always easy to do a thing, when another has done it well and told us how. But it must be remembered that a hypothesis of this sort, though normal enough in our day, was very abnormal in that day; indeed, it was contrary to Darwin's own underlying conceptions, for, though a uniformitarian, he had seen many phenomena which, for a time, made him only a halting disciple. Yet his hypothesis was a monumental contribution in support of the uniformitarian doctrine, which, under the leadership of Lyell, was gaining sturdy adherents. That the hypothesis met with uncompromising opposition need not be said. The material of coral origin extended to vast depths alongside of the islands, in some cases apparently to 4,000 feet. The upward growth of the reef was known to be extremely slow. If the subsidence and the upward growth kept pace, as was essential to the hypothesis, evidently the required period, belonging to the latest portion of the earth's existence, was immensely long. It is difficult now to understand how great moral courage was needed by the man who published such a doctrine; sixty years ago, the educated man

of Great Britain had not learned to distinguish between faith and prejudice.

This effort to explain the origin of coral reefs has been regarded, justly, as Darwin's especial contribution to geology. It has been opposed strenuously by careful students during the last twenty years and even now it is a bone of contention; but the most strenuous opponent concedes that it is logical and a fair induction from the facts as then known. Be it true or not, be it a competent explanation or not, no matter. In influence on geology it has been as far-reaching as the doctrine of natural selection has been on biology. It involves every important problem in dynamics of the earth's crust; in testing it, men have been led into paths of investigation, which, but for Darwin, might still be untrodden. The influence went farther. The hypothesis was presented at a time when men's minds were warped by prejudice, when men were extremists, when too many were defenders of dogmas in science and too few were searchers after truth. Darwin's discussion was a model of frankness; suggestions offered by his predecessors were dealt with courteously; he searched far and wide for objections to his own suggestions, and when objections were found, he stated them in detail, concealing nothing and urging further investigation. His conclusions were, for him, merely tabulations of observed facts. One can not overestimate the importance of this method; it was a chief factor in changing the tone of scientific literature, in leading to replacement of subjective by objective modes of investigation.

Darwin's work as geologist practically ended with these publications of the *Beagle* results. It is true that in later years he made some contributions possessing much interest, but they were merely incidental to studies in other directions; the greater part of his long life was devoted to biological problems. At the same time, his whole mode of thinking and of observing was that of the geologist, so that if one were treating of his later years the topic might well be the influence of geology upon Darwin. In his later works, one finds constantly recurring consideration of geological conditions as potent factors in biological change, while on the other hand he emphasized the influence of life as a factor in bringing about geological changes. To him nature was always one; and he, in great measure, was responsible for the broadness of view characterizing the geologists who were his contemporaries as well as for the remarkable change in attitude of the community toward scientific discussion. Nowadays, when workers are so many and knowledge is so increased, men have been forced into narrow lanes of investigation; students, perplexed by phenomena within their limited vision, too often think little and know less of what neighbors are doing. And this must continue until some important problems have been solved, at least in part, and some positive results have been obtained in many directions.

Then another Darwin will come, will gather loose strands floating in the wind and will weave from them a new system, once more binding nature studies into one and providing a safe platform, whence men may start anew to fathom the unknown by means of the known.

DARWIN AND BOTANY.

By Dr. Nathaniel Lord Britton.

Considering the fact that Charles Darwin disclaimed the title of botanist, his contributions to the knowledge of plant life and its phenomena were certainly extraordinary. His investigations extended over a great range of topics, at one time or another practically covering the whole field of botanical research. In repeatedly stating that he was not a botanist, he evidently meant to imply that he was not a systematist, and it is true that his knowledge of plant taxonomy was the least of his scientific acquirements. In his first letter to Dr. Asa Gray, written in 1855, which was the commencement of a long correspondence, he almost apologized for asking questions! During that year he became keenly interested, however, in knowing more about the kinds of plants growing wild in the vicinity of his home, and in a letter to Dr. Hooker he complains about the dreadful difficulty of naming plants, though he apparently became quite enthusiastic in this pursuit and advised Dr. Hooker, "If ever you catch quite a beginner and want to give him a taste of botany, tell him to make a perfect list of some little field or wood." The facts just stated seem to indicate the extent of his taxonomic studies. He accepted, for the most part, the names of plants which he studied from the determinations of others.

Darwin was attracted to observations of natural objects as a young boy and he early considered plants; his juvenile collections were entomological, and his earlier investigations were mainly zoölogical and geological. As a pupil of Professor Henslow at Cambridge University he attended botanical lectures and took part in field excursions; he greatly enjoyed the field work, and from it his inspiration for investigation was doubtless derived.

As naturalist of the voyage around the world of the ship *Beagle* (1831–1836) his collections of plants made in South America and on the islands of the Pacific Ocean, and his observations upon the botanical features of the countries visited, contributed greatly to the knowledge of the flora of those regions. They were extensively utilized by Dr. Hooker in his "Flora Antarctica" and in his "Flora of the Galapagos Archipelago," as well as

by other authors in various contributions. Darwin's valuable herbarium is preserved in the museum of Cambridge University. That he collected assiduously at times during portions of this expedition, is evidenced by his having brought home specimens of 193 species of the 225 species which, after his specimens had been studied, were known to inhabit the Galapagos Islands and by the fact that about 100 species new to science were represented in his Galapagos collection. He noticed the extraordinary distribution of species or races on the several islands of this group, many of them inhabiting only a single island, and he laid the foundation for all subsequent study of insular floras. The narrative of observations and experiences during this memorable voyage is replete with interesting facts and suggestions concerning plants, and his conclusion that "Nothing can be more improving to a young naturalist than a journey in distant countries," is one that should be reiterated by all teachers of natural science, and such experience should be sought by all students who propose engaging in investigation. Darwin is commemorated in botanical taxonomy by many species named in his honor. The beautiful barberry, *Berberis Darwinii* of Hooker, native of Chiloe, is occasionally seen in cultivation. *Darwinia,* an Australian genus of the myrtle family, named by Rudge in 1813, commemorates his grandfather, Erasmus Darwin.

The beginnings of Darwin's theory of descent of animals and plants from preëxistent species, with modifications, were made during the voyage of the *Beagle*, and from the year after his return to England, when, he tells us he opened the first note-book on the subject. For twenty-two years he was interrogating gardeners and breeders, botanists and zoologists, and diligently observing plants and animals. He first thought of publishing on the theory of descent in 1839, but delayed for twenty years. During the studies which led up to the publication, in 1859, of "The Origin of Species by Means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life," Darwin closely observed a great number of wild and cultivated plants, with reference to variation in nature and under domestication, the struggle for existence due to competition for food and sunlight, the facts of geographic distribution, the succession of plant life on the earth as indicated by the fossils of successive geologic periods, and a great range of other facts and phenomena. The recorded observations of other botanists were also freely utilized and discussed. Nearly all the chapters of this epoch-making work contain conclusions drawn from his own botanical observations. He was especially impressed by the divergent views of different botanists relative to the taxonomic treatment of highly polymorphic genera such as *Hieracium* (hawk-weed), *Rubus* (blackberry), *Quercus* and *Rosa,* and he employed this consideration to great advantage in his argu-

ment for derivation during descent. Rudimentary organs were considered with much interest and readily explained by Darwin as vestiges of structures which were useful to the plant in earlier stages of its existence. The facts of geographic distribution were eagerly examined as bearing on the theory of descent, and Darwin's writings abound in speculations relative to their significance. He was inclined to combat the geologic theory of former land connections of present existing continents, as not satisfactorily accounting for many features of geographic distribution, though he ultimately agreed with this theory to some extent. He closely studied the natural means by which seeds are transported over great distances and also inquired into the vitality of seeds.

The title of the "Origin" was a subject of considerable doubt in his mind, and in 1857, two years before it was printed, he had proposed to call it "Natural Selection." The title "Origin of Species by Means of Natural Selection" is, if taken literally, somewhat misleading and has occasioned considerable discussion. The subtitle — "Or the Preservation of Favored Races in the Struggle for Life" — is a more accurate statement of his theory. On November 23, 1856, he wrote to Dr. Hooker:

> The formation of a strong variety, or species, I look at as almost wholly due to the selection of what may be incorrectly called chance variations. Again, the slight differences selected, by which a race or species is at last formed, stand, as I think can be shown in the far more important relation to its associates than to external conditions.

Darwin's great contribution to the subject of evolution was the incontrovertible proof adduced by him that living species are modified descendants of preëxisting species, and that the modifications are brought about by natural causes. His observations led him to the conclusion that the modifications were all minute, gradual and cumulative. We know that they may also be considerable and abrupt and that they are cumulative because favorable changes are preserved.

How, then, do the modifications or primordial variations, either large or small, arise? Is variation an innate essential quality, or is it induced by external environmental factors? Proof of environmental agencies having at least something to do with it in plants seems to be accumulating, as the experimental work carried on by MacDougal and by Gager at the New York Botanical Garden appears to imply.

I think that we may now safely outline the methods of formation of species somewhat as follows: Through causes which are not yet at all well known, but by means of which agencies external to the germ-cells certainly may have a part, the offspring of a plant grown from seed differ more or

less from the parent (variation). The thus modified offspring, subjected to natural selection, ultimately perish if they are unadapted, but survive if they are adapted to their surroundings. Repetitions of this process finally bring the descendants of plants to differ materially from their ancestors (evolution). The end of the process seems to be the development of organisms which are little or not at all subject to variation (monotypic genera). All genera of plants containing a large number of species are evidently subject to continued variation, and their species and races almost defy classification. Just what part the phenomena of hybridism take in the final result is not clear, but it may be pointed out that they are evidently unnecessary, because great groups, whole orders, in fact, of the fungi, are devoid of sexuality, and hybridism is therefore impossible among them; yet they are subject to variation like other plants and quite as difficult to classify.

Observations on insectivorous plants occupied Darwin at intervals from 1860 until the publication of his volume on that subject in 1875. He commenced with the round-leaved sundew (*Drosera rotundifolia*) while staying at Ashdown Forest, and was soon intensely interested in the exquisite sensitiveness of the leaf-glands to nitrogenous substances. His studies were continued over most of the plants of the sundew family, and to others known to entrap insects or other small animals. He discovered that the leaves of *Drosera* and of *Dionæa* secreted a ferment when supplied with various kinds of nitrogenous food and he closely observed the movements of their glands and tentacles and recorded them in detail. Experiments were also made on these plants with a great variety of non-nitrogenous substances. Darwin pointed out the remarkable parallelism between the digestive powers of the secretions of the Droseraceæ and those of the gastric juices of animals. The sacs of the aquatic bladder-worts (*Utricularia*) and the leaves of butter-worts (*Pinguicula*) were also closely studied. His book is replete with records of careful observations and ingenious deductions. *Nepenthes* had already been shown by Dr. Hooker to secrete digestive fluids in its pitcher-like leaves, and *Sarracenia* was suspected of similar activity by Darwin and by others, although he did not regard this as proven.

As early as 1838 or 1839 Darwin was attracted to observe the processes of pollination and noticed the dimorphic flowers of *Linum flavum*. He had concluded at that time that cross-fertilization was potent in holding species stable and constant. He obtained a great deal of information on this topic in 1841 by reading Sprengle's "Entdeckte Geheimniss der Natur," which stimulated him to continued investigations during summers and he became especially interested in the methods of pollination of the wild orchids growing about his home. This study of pollination of orchids resulted in the publi-

cation, in 1862, of his book on that subject, and in it his detailed observations are recorded. Some of his closest observational work was done on this subject of cross-pollination, and he examined a great many species and grew thousands of plants from seed, reaching the broad generalization that cross-fertilization is beneficial to a species and self-fertilization is injurious. The phenomena do not now, however, appear to have as important a relation to evolution as they were formerly supposed to have, and Darwin later expressed regret that he had not given more attention to the processes of self-fertilization.

His interest in showing that cross-fertilization was beneficial led him to investigate closely the various structural features of flowers which necessitate this process to a greater or less degree, such as diœcism, monœcism, polygamy and heterostyly; his observations and speculations are presented in the volume entitled "Different Forms of Flowers and Plants of the Same Species," published in 1877. He records that making out the meaning of heterostyled flowers gave him very great pleasure. A chapter of the book is devoted to cleistogamic flowers, which are necessarily self fertilized and produce seed abundantly. This work is largely a revision and rearrangement of several papers previously published in the *Journal of the Linnæan Society.*

"The Variation of Animals and Plants under Domestication," Darwin's largest work, appeared in 1868, published in two volumes. As bearing on this topic, he had studied, among plants, for many years, the cereal grains, garden vegetables, edible fruits, ornamental trees and ornamental flowers. In the preface he again discusses natural selection and defines it as "This preservation, during the battle for life, of varieties which possess any advantage in structure, constitution or instinct," noting that Herbert Spencer had well termed the same process "The Survival of the Fittest." But the bulk of the work is given to the consideration of selection by man — artificial selection, by which races useful to us, economically or esthetically, have been preserved and modified, some of them having originated in very remote times and been taken advantage of by uncivilized man. A chapter is devoted to the phenomena of bud-variation, in which many cases of branches of plants different in one respect or another from other branches on the same plant are described in detail. Many of these have been taken advantage of by horticulturists for the propagation of valuable races. He did not reach any definite conclusion as to the cause of these interesting occurrences; but recently acquired knowledge of mutation seems to indicate that they are of that category, differing from seminal mutations in that a cell in the axil of a leaf is affected rather than a germ-cell. In these volumes we find Darwin's most detailed discussion of heredity, of variability and of hybridism and the last chapter outlines his provisional hypothesis

of pangenesis, an ingenious supposition, applying to living matter the general features of the atomic theory, with an additional inherent power of reproduction of the atoms or "gemmules" as he termed the hypothetical ultimate particles.

The movements of plants and of their various organs were also studied by Darwin for many years. His first essay on this topic appeared in 1865 and ten years later he revised and enlarged it as a book under the title "The Movements and Habits of Climbing Plants," using, as always, not only his own detailed and extensive observations, but also the published writings of other botanists, among them the paper on tendrils by Hugo de Vries, who was destined subsequently to throw such a flood of light on the phenomena of variation. Darwin grouped climbing plants into twiners, leaf-climbers, tendril-bearers, hook-climbers and root-climbers. He maintained that the climbing habit has been developed to enable vines to reach the light and free air; tropical forests show conclusively that this is the case. He showed that circumnutation, the bending of growing tips successively to all points of the compass, is a general phenomenon among flowering plants, and he thought it of high importance to them. The sensitiveness of tendrils to external influences interested him deeply, and he made many original experiments upon them. Following the subject much further he published in 1880 the work entitled "The Power of Movement in Plants," a treatise abounding in records of original observations on seedlings and parts of mature plants, including further studies of circumnutation, of the sensitiveness of plants to light and to other forces and of the phenomena of geotropism and apogeotropism, which he regarded as modified phenomena of circumnutation.

The value of the impulse given by Darwin to botanical investigation in all its branches is beyond estimation; his power of exact observation and record has seldom been equaled and certainly never excelled; his deductions were highly philosophical, and most of them have stood the test of thirty years' inquiry and criticism; he was searching for truth and his absolute honesty in research is plainly evidenced by his repeated criticism of his own conclusions.

The immense number of plant species which had been described and named, and the lack of any complete index to them led Darwin to provide in his will for complete enumeration of the names of published species of flowering plants. This great work was prepared at the library of the Royal Gardens, Kew, England, and published in 1895 in four large quarto volumes, to which several supplements have since been added. This "Index Kewensis" is a great boon to all investigators, and is quite indispensable to those who have to take plant names into consideration.

DARWIN AND ZOÖLOGY.

By Dr. Hermon C. Bumpus.

This is an assembly composed substantially of members and friends of the New York Academy of Sciences, united to do homage to one whose genius has been long felt in our meetings, and whose influence is now recognized in every field of intellectual endeavor. The example of Darwin's precision in observing, of his wisdom in interpreting and of his truthfulness in recording the phenomena of nature has transformed zoölogy — the subject assigned to me — from prosaic description to acute speculation, from a merely interesting study to an aggressive science.

This change took place in an incredibly short space of time, and it may be worth while, on an occasion such as this, to examine the condition of scientific academies and similar organizations in America at the time of the publication of the "Origin of Species," to note the first center of appreciative acceptance and to trace the spread of the belief in Darwinism as it betrayed itself in the publications of the time.

Fifty years ago there were in America five leading centers of organized scientific activity.

In Philadelphia were the American Philosophical Society, founded by Franklin and then well along in its second century of "promoting useful knowledge," and the Academy of Natural Sciences, approaching its semi-centennial.

In Boston were the adolescent Boston Society of Natural History, approaching its thirtieth birthday, and the mature American Academy of Arts and Sciences, founded in 1780.

In New Haven was the Connecticut Academy, founded in 1786.

In Washington, although the National Institution for the Promotion of Science (founded in 1840) and the Smithsonian Institution had been publishing for eleven years, men of science apparently did not unite in an academic way until the Philosophical Society of Washington was organized in 1871. Even the National Academy was not incorporated until 1863, four years after the announcement of the "Origin of Species."

In New York, this academy (then called the Lyceum of Natural History) was meeting at Fourteenth Street, at a point now occupied by the headquarters of Tammany Hall. Of those then attending its meetings, but one now remains.

The dominant mind at Philadelphia was that of Leidy, thirty-six years of age. Cope was a boy of nineteen. In Washington, were Joseph Henry,

sixty-two; Bache, sixty-three; Baird, thirty-six, and others attached to the Smithsonian Institution, and the great government surveys. Baird was often a contributor to the publications of the New York Lyceum of Natural History.

In New York was Torrey, a man of sixty-three, and among others two young men, Theodore Nicholas Gill — the senior member of this academy — and Daniel Giraud Elliot, now honoring this museum with his presence — both born in New York, and both in their early twenties. Not only have these two — early identified with the scientific publications of this academy — witnessed the change that has taken place during the past fifty years, but their long series of contributions to science admirably illustrate the strange power that has been exerted upon zoölogical work in general, and descriptive zoölogy in particular, by him who came into being one hundred years ago.

In New Haven were James Dwight Dana, forty-six, Daniel C. Gilman, twenty-eight, and the Sillimans.

In Boston, were Agassiz, adored by the people — preëminent among teachers — the studious lovable Gray, at one time (1836) librarian of this academy, and Jeffries Wyman. Both Agassiz and Gray were about the age of Darwin. Jeffries Wyman was a few years their junior; of him Lowell has written:

> He widened knowledge and escaped the praise
>
> . . . .
>
> He toiled for science, not to draw men's gaze.

Under the influence of these, Agassiz, Gray, Jeffries Wyman, there gathered at Cambridge, at about this time, what we would now informally and affectionately call "a bunch of boys." Shaler, eighteen; Verrill (who has come down from New Haven to be with us this afternoon) and Packard, twenty; Morse, Hyatt and Allen — our Dr. Allen — twenty-one; Scudder, twenty-two.

Of the five centers of scientific activity, youth was certainly the characteristic of the school at Boston. It is therefore safe to predict that the germ of the new truth in biological science would find a more favorable medium in Boston than here in New York or farther south.

The infection was immediate, indeed "*pre*-immediate." The period of incubation extended over about ten years, ending in an acute epidemic from 1871–1876, which affected lyceums, associations and academies indiscriminately. Convalescence then began, since which the American body-scientific has enjoyed good health and has shown many periods of remarkable growth.

The "Origin of Species" was published in London late in November, 1859. The following month, Asa Gray, long intimately acquainted with Darwin, and anxious that Americans should see promptly the significance of the new theory, wrote for *Silliman's Journal* a review of the book, before a single copy of the "Origin" had reached this country. He predicted that the work would produce great discussion — it did. A copy arrived, it was carefully reviewed, but before the review could be gotten through the press, a second edition was announced, and within three months two American editions were advertised.

Gray gave his first review in December. In January, Professors Agassiz, Parsons and Rogers are recorded as having discussed the "Origin and Distribution of Species" at a meeting of the American Academy of Arts and Sciences on Beacon Street. Gray was present. In February, Agassiz began his open opposition to the theory of Darwin, stating at the Boston Society of Natural History that, while Darwin was one of the best naturalists in England, his great knowledge and experience had been brought to the support of an ingenious but fanciful theory. In these discussions Professor Rogers valiantly upheld Darwin's views. In March, Agassiz continued to oppose Darwin, and in April, Gray and Parsons made their reply. In May, they were at it again. Then followed the admirable essay of Parsons, Professor of Law at Harvard, and the unfortunate advance sheets of the third volume of Agassiz's "Contributions." Then came Gray's *Atlantic Monthly* articles, and thus ended the first year.

Among the records of the learned societies of New York, Philadelphia and Washington, I can find nothing to indicate that there was any particular interest in the disturbances that were going on in and about Boston. Professor Dana, easily the dominant figure in science at New Haven, was in poor health and out of the country, but it was generally considered that his intensely idealistic views would probably have prevented him from accepting a theory that was felt by many to be grossly materialistic. The infection therefore was local and remained local about Boston for a full decade.

In 1861 Agassiz doubtless discussed the matter before the National Academy in a paper on the "Individuality of Animals," but I have been unable to find a copy of the paper.

In 1863 Jeffries Wyman, in his review of Owen's monograph on the "Aye-aye" gave inference of his adherence to the theories of Darwin, and indicated the impossibility of there being any neutral ground.

In 1865 Morse came to New York from Salem to be the guest of this academy, but the formal paper that he presented did not contain even a remote allusion to the discussions that were going on in what was then considered America's educational center.

In 1867 Hyatt's paper on "Parallelism" appeared. This I believe to be the first distinctly evolutionary contribution from the zoölogical side. In this year, 1867, Professor Newberry, later and for twenty-three years the president of this academy, delivered his address at the Burlington meeting of the American Association for the Advancement of Science, betraying in this a singular nobleness of character toward those to whose advanced views he felt that the scientific world could not entirely subscribe, and admirably illustrating what he interpreted to be the prevailing opinion as shown by the following quotation:

Although this Darwinian hypothesis is looked upon by many as striking at the root of all vital faith, and is the *bête noire* of all those good men who deplore and condemn the materialistic tendency of modern science, still the purity of life of the author of the "Origin of Species," his enthusiastic devotion to the study of truth, the industry and acumen which have marked his researches, the candor and caution with which his suggestions have been made, all combine to render the obloquy and scorn with which they have been received in many quarters, peculiarly unjust and in bad taste.

This was also the first year of the *American Naturalist*, edited by those four pupils of Agassiz — Packard, Morse, Hyatt and Putnam — of whom two are still spared. The introduction of the charming first volume of this characteristic American publication is sufficient proof that at the time of its issue even the younger men felt that there were two distinct schools of thought relative to the "Origin of Species." Those who are familiar with the introduction will remember that it is illuminated with one of Morse's inimitable sketches, a snail peering through a binocular microscope, symbolical, doubtless, of the slowness of perception of those who clung to this archaic instrument and possibly also of those who clung to archaic ideas.

The following year, 1868, the Academy of Natural Sciences of Philadelphia, which in 1860 had elected Darwin to membership, published the first important direct contribution to the subject of evolution made by one not directly under the influence of the Boston academies. This contribution, "On the Origin of Genera," was made by Cope, who for several years had been submitting papers to the academy of a descriptive and semi-speculative character, and largely dealing with the classification of reptiles. I believe that I am perfectly safe in saying that no academy in America has ever published a paper that reflects more to its credit than this extraordinary essay of Cope. It is apologetically issued as a fragment, but in it there is shown an intimate acquaintance with anatomical detail that is almost supernatural, an independence of thought that is extraordinary, a power of analysis that stuns the reader, an estimate of the weak and the strong points of the Darwinian theory that is masterly, an agility of logic that marked its author

as a dangerous antagonist, an energy to reach the truth, and an impetuosity to convince others of truth, that was prophetic, indeed, that was completely demonstrative of pent-up mental power which must have been most disturbing to those of his academy who had nestled down into positions of comfortable intellectuality.

We now enter upon five years of acute activity.

On December 15, 1871, Cope attended a meeting of the American Philosophical Society, and presented his paper on "The Method of Creation of Organic Forms." In a fortnight a reply was given, which began with a quotation from Job: "I am a brother to dragons and a companion to owls," and continued for several pages in attempted explanation and demonstration of the falsity of Darwin's theories, and ended with the author's conviction that the only good that can come from these theories is the fact that they must bring about their own defeat. Cope replied immediately and was then replied to, and so on. But why follow the discussion?

The spell was being felt even farther south. Within two months of the date of its founding, the Philosophical Society of Washington listened to a paper by Professor Gill, in which it was stated that if the doctrine of evolution was accepted at all, it must involve man.

This was also the date of Dr. Allen's paper on the "Geographical Variation of North American Birds," a philosophical as well as descriptive article, an important contribution to the then scant literature of distribution, a paper which established a distinct method of zoological research that has reflected the highest credit on its author and on the institutions with which he has been connected.

It was also in this year that Morse published his paper on "Adaptive Coloration."

In January, 1872, the New York Academy made its first direct contribution to the subject of evolution by publishing a brief paper on the "Carpus and Tarsus of Birds." I hope that Professor Morse, now forty-five years a member of this academy, is present at this gathering, for the fifty years that have passed since the appearance of the "Origin of Species" exactly synchronize with the period of his devotion to the principles enunciated therein. If, among the volumes of this academy from 1859–1876, one binding shows more signs of use than the others, take down the book, and you will find that it opens to this article by Professor Morse; a contribution to zoölogy, to comparative anatomy, to embryology and to the theory of evolution. It is a refreshing spot, but somewhat out of place in an arid expanse of descriptions of new species and revised classifications.

Another paper issued by the academy in 1872, and characteristic of the new thought of the time, was by Benj. M. Martin on the "Unity of the General Forces of Nature," but this was physical rather than biological.

If one were forced to accept the presidential addresses of the American Association for the Advancement of Science as indicative of the advancement of science in American associations, the address of 1873, delivered by one who said he thought that natural selection had died with Lamarck, would be sadly misleading. He writes:

In Darwin we have one of those philosophers whose great knowledge of animal and vegetable life is transcended only by his imagination. In fact, he is to be regarded more as a metaphysician with a highly-wrought imagination than as a scientist.

But this is only the beginning of the gloom that anticipated the dawn.

Although in 1874 Dr. Elsberg, in a "Contribution to the Doctrine of Evolution," addressed this academy (and also the American Association for the Advancement of Science), in favor of the principles of Darwin, although Cope continued to sustain his earlier contentions, and general workers were beginning to make original observations in favor of the principles of organic descent, the reviewers of the deliberations of scientific gatherings gave little promise of anything like a general acceptance of the beliefs in which we are interested.

In 1875, the retiring president of the American Association said:

I fear that the unhappy spirit of contention still survives, and that there are a few who fight for victory rather than for the truth.

One of the vice-presidents at this meeting declined to "enter on the vast field of discussion.... opened up by Darwin and others," and resolved to avoid the use of the word "evolution," "as this has recently been employed in so many senses as to have become nearly useless for any scientific purpose."

Thus closed five years of struggle.

The year 1876, the centennial of political independence in America, marked also the dawn of intellectual independence and scientific freedom. It was the year of Brooks's first *Salpa* paper, and of his paper on pangenesis. Cope explicitly stated that the law of natural selection was now generally accepted, and the then librarian of this academy, Louis Elsberg, submitted his paper on the plastidule hypothesis, as nonchalantly as though he were discussing the lingual ribbon.

It was under these really blessed conditions that the American Association met in Buffalo and listened to a vice-presidential address fully worthy the title of the organization. Edward S. Morse had demonstrated his ability as an investigator in his paper of 1872, already mentioned, but the simple, straightforward, patient and kindly manner in which he addressed his audience in 1876, the thoroughness with which he scanned the work of

others, the fairness with which he acknowledged the value of their results, and his concluding passages, in which he indicated the important bearing that the theories of descent had upon the social problems of the day, render his address a fit conclusion of a distinct epoch in the history of American science.

Since 1876, practically every zoölogical worker has sought to make some contribution that might strengthen his faith in a rational evolution of organic life and activities. It may be that such contributions will prove insufficient. It may be that Darwinism as a *thing* will ultimately fail of proof, but to those in the future who may inquire for the reason for these exercises and for the erection of this monument, *Darwinism as a method* will ever be a sufficient reply.

[ANNALS N. Y. ACAD. SCI., VOL. XIX, No. 2, Part I, pp. 41–44. 20 April, 1909.]

GEOLOGICAL CORRELATION THROUGH VERTEBRATE PALEONTOLOGY BY INTERNATIONAL COÖPERATION.

Correlation Bulletin, No. 1. Plan and Scope.

BY HENRY FAIRFIELD OSBORN, *Chairman*, AND W. D. MATTHEW, *Secretary*,

Section of Vertebrate Paleontology, International Correlation Committee, National Academy of Sciences.

This is the first of a series of Correlation Bulletins which will be successively published in the *Annals of the New York Academy of Sciences*, as reports of special researches on geologic correlation through vertebrate paleontology. These researches have been instituted through a committee appointed by the National Academy of Sciences in 1908, with the special object of securing international coöperation in paleontology, similar to that which has proved so helpful in astronomy. The research is facilitated through a grant from the Bache Fund of the National Academy of Sciences, founded in 1879. The Council of the New York Academy of Sciences has agreed to coöperate with this important work by the publication of the series of correlation bulletins.

In this first bulletin it seems desirable to outline the history of organization and proposed method of procedure of the Committee. Correlation Bulletin No. 2, entitled "Fossil Vertebrates of Belgium," contributed by Dr. Louis Dollo, of the Royal Belgium Museum of Natural History, will afford a practical illustration of the methods proposed.

I Organization of Committee.

At a meeting of the National Academy of Sciences, April 22, 1908, it was resolved:

"That four members of the Academy be appointed by the President as a Committee on Paleontologic Correlation, including two specialists in Invertebrate and Vertebrate Paleontology, respectively. The committee shall report at each meeting. The present committee shall serve

two years only and be eligible to reappointment or substitution of new members in 1910. The committee shall have power to extend its membership so as to secure American and international coöperation."

Pursuant to the terms of the above resolution, Messrs. C. D. Walcott, H. F. Osborn, W. H. Dall and W. B. Scott were appointed as a committee on Coöperative Research in Paleontologic Correlation, with power to add to their number. The object of the committee was to obtain through coöperative research by European and American paleontologists a better and more exact correlation of geological horizons. The method of procedure was left to the discretion of the committee.

The committee found it advisable at the outset to divide into two sections, on vertebrate and invertebrate paleontology respectively. Dr. Osborn was made chairman of the vertebrate, Dr. Walcott of the invertebrate section. Dr. T. W. Stanton was invited to accept the secretaryship of the invertebrate and Dr. W. D. Matthew of the vertebrate section.

The following paleontologists were invited to become members of the committee and have signified their acceptance.

Professor Louis Dollo of the Royal Museum of Natural History, Brussels, Belgium,
Professor Charles Depéret of the University of Lyons, France,
Professor Eberhard Fraas of the Stuttgart Museum, Germany,
Professor Ernst Koken of the University of Tübingen, Germany,
Dr. F. von Huene of the University of Tübingen, Germany,
Professor S. W. Williston of the University of Chicago.

Other members may be added as the work progresses, and invitations will be extended to various other paleontologists to assist in special parts of the work. Prof. J. C. Merriam, of the University of California, has kindly agreed to assist in the correlation especially of the California and Sierra Nevada sections.

It is intended to distribute the correlation of the different geological periods in Europe and America among the several members of the committee, their evidence and conclusions to be reviewed and the broader and final correlation made by the committee as a whole.

II. Method of Procedure.

It is desirable in the first place to get the data together and point out the weight and bearing of the evidence. This may best be done by means of annotated lists of typical faunæ. These may be drawn up, reviewed, revised

and critically considered for each typical vertebrate fauna. These faunal lists may then be published, as reports of progress, without committing individuals or the committee to decisions upon the wider questions of correlation. They will serve rather as summary statements of the evidence available. These broader correlations can then be taken up by sub-committees composed of authorities upon vertebrata, invertebrata and plants, and the final decisions made by comparison and criticism of the evidence from these groups and upon such other evidence as may appear pertinent. Decisions of sub-committees, reviewed and approved by the committee as a whole, will then serve for a broad standardization.

The first necessary preliminary is to get the data together in the following form:

1. Lists of typical and well-known faunæ, strictly arranged by formations and horizons or by geological distribution. These should include, as far as practicable, the character and location of type, character of referred specimens, etc., in order to give some idea of how much is known of the species and its consequent value in correlation. Genera and species known from complete and abundant material are naturally of much more value in correlation than those reported from scales, teeth or other fragments.
2. Critical observations upon the importance of the species or genera in correlation; their relations to others occurring in other typical faunæ; first or last appearance of genera and families; abundance of the species or genus; range, time and direction of migration, and any other data of value in this connection.
3. Sketch geological sections of type localities showing the level of occurrence of the fossils and relations of overlying and underlying formations. Sketch maps showing the location and extent of the formations.
4. Principal literature, chief scientific collectors who have worked in the field, with the date of their work, estimate of its probable accuracy and possible sources of error in correlation.
5. Geographic and geologic conditions, environment and phase represented by the fauna as a whole.

Dr. Matthew has in preparation lists of the American faunæ which will be submitted to American members of the committee for critical observations and sketch sections. Similar data are desired for European and foreign typical faunæ. These data, when compiled, will be published from time to time as reports of progress, and the final results will be based upon consideration and correlation of these reports.

III. Progress of Correlation Work.

Dr. Louis Dollo's valuable detailed report upon the succession of vertebrates in the Mesozoic and Cenozoic horizons of Belgium is accompanied by a full description as to location of types, etc. This report has been translated by Dr. Matthew and is to appear as Bulletin No. 2.

Dr. Osborn has continued his researches on the correlation of the Cenozoic, especially of France and of North America, in coöperation with Professor Charles Depéret in France and Dr. W. D. Matthew in North America. A preliminary report on this correlation is now in course of publication by the United States Geological Survey.

Dr. W. D. Matthew has completed a full series of faunal lists of the Tertiary Mammalia of North America which also are ready for publication. The lists of other vertebrates, that is, Reptilia, Aves and Amphibia, are completed down to the year 1900 with the data, so far as readily obtainable.

[ANNALS N. Y. ACAD. SCI., Vol. XIX, No. 1, Part 3, pp. 45–97.]

STUDIES ON THE MORPHOLOGY AND DEVELOPMENT OF CERTAIN RUGOSE CORALS.[1]

BY THOMAS CLACHAR BROWN, A. M.

CONTENTS.

[1] Read at the meeting of the Academy, 1 March, 1909.

I. Introduction and Historical Sketch.

Although the rugose corals have been known and studied for more than a century, it was not until very recently that the fundamental principles of their structure and mode of development were understood. Kunth, in 1869, first stated the law which governs the arrangement of septa in the majority of rugose corals, namely the appearance of main or cardinal and counter septa in one diameter of the calyx, and of two alar septa in the cross diameter; and the appearance of additional "pairs" of septa on either side of the main septum and on the remote side of each of the alar septa.

The morphological structure and method of development of these corals was clearly grasped by the late Carl Rominger, as is evident from the following quotation from his treatise on the corals of the Lower Peninsula of Michigan, published in 1876.[1]

> The radial plications of the zoantharia rugosa are arranged in four primary fascicles, separated from each other by more or less conspicuous gaps. These fascicles, apparently segments of a cycle of rays, are in reality bilaterally situated in symmetrical position on an axial line, dividing the apparent cycle in two halves. The two fascicles on one side are equivalent to those of the opposite side, but differ from one another. For better illustration we may compare the circumference of a polyp cell to a horse shoe with narrow, almost closed aperture. Opposite this aperture, in the center of the curve, two fascicles meet with their equivalent sides, having an obscure narrow gap between them, the center of which often exhibits a solitary independent plication. This gap may, in distinction from the other gaps, be designated by the name of *central gap*. At the ends of these fascicles, remote from the central gap, and directed toward the aperture of the horse shoe, the plications become gradually shorter, and, seen from the peripheral surface of the polyp cells, do not extend to the apex of the conical polyparium, but terminate above, nearer the calycinal margin. Another gap separates these shorter plications on each side from the adjoining fascicles of plications, which extend to the ends of the arms of the horse shoe. This pair of gaps is the *lateral gaps*. The further ends of this second pair of fascicles approach each other again, in the aperture of the horse shoe, leaving another larger gap between themselves than the other facicles, which may be termed the *apertural gap*; its center is like the opposite obscure gap, occupied by a solitary plication. The plications of this second pair of fascicles are longest and extend to the apex of the polyparium on their end joining the lateral gaps, and shortest at the apertural gap. This is the order in the structure of all the polyp cells of the Zoantharia rugosa. If, during the progress of growth, new plications are added to the cycle of existing ones, the new ones are only inserted at those ends of the four fascicles which are directed toward the apertural gap, while the already existing plications are never disturbed by interposition of new ones, excepting as indicated at the four ends of the fascicles, directed toward the apertural

[1] Paleontology of the Lower Peninsula of Michigan, Vol. III, pp. 92–95, 1876.

gap; furthermore the addition of new plications at the four ends of the fascicles is not always contemporaneous in all, or in the opposite corresponding ones, for otherwise the lamellæ in each equivalent bundle should be equal in number, which is not always the case. This bilateral structure of the polyp cells of the Zoantharia rugosa has been observed by several paleontologists, and been mentioned by them as a peculiarity of certain species; but the late Dr. Kunth, of Berlin, was the first to demonstrate this bilaterality to be an essential character of all the Zoantharia rugosa, and to exhibit with clearness the peculiar mode of multiplication of the lamellæ in this order. If we examine a Streptelasma or a Zaphrentis, we find the outer surface of the polyp cells longitudinally striate, by broad convex bands or ribs, and by intermediate narrow linear furrows. The furrows correspond to the crest-like plications on the inside of the calyces, the ribs to the interstitial spaces between them. Three of such longitudinal furrows are, on each of the polyp cells, more conspicuous than the others; they correspond to the gaps between the bundles of lamellæ. In the furrow corresponding to the apertural gap, the other furrows from both sides converge at an acute angle, like the barbs of a plume to its keel, gradually becoming shorter as they approach the margin of the calyx. The two other obvious furrows, corresponding with the lateral gaps, are, on the side nearest to the apertural gap, joined by similar parallel furrows extending into the apex; on the other side the furrows abut against it at an acute angle, and decrease in length as they ascend. The central gap is not indicated on the outside, because the furrows on both its sides are parallel with it, as new plications are never intercalated in this place.

This interpretation of the structure of these corals stood almost unchallenged for a quarter of a century, till called in question by Duerden in 1902. R. Ludwig, in papers published in H. von Meyer's "Palæontographica," vols. X and XIV (1865–66), had described and figured certain rugose corals as hexameral in symmetry, but his interpretations were so fanciful and erroneous that they did not excite much serious consideration. In 1871 Count L. F. de Pourtales[1] also claimed to have discovered that the rugose corals were originally hexameral in symmetry and speaks thus of Ludwig's observations and his own:

Mr. R. Ludwig has shown that the tetrameral arrangement claimed for the Rugosa is only apparent, there being originally six primary septa, but that further development in each system is asymmetrical and that two of the systems remain generally undeveloped. I had, before having knowledge of Ludwig's researches, come substantially to the same conclusions by the examinations of *Lophophyllum proliferum* Edw. & H., from the Carboniferous formation, a form very suitable for the study..... When the youngest stage of the coral is examined by cutting through the tip of the conical *Lophophyllum proliferum*, six primary septa and six interseptal chambers are found, placed symmetrically on two sides of a vertical plane, and unequally developed.

[1] Deep Sea Corals, Ills. Cat. Mus. Comp. Zool., Harvard College, Vol. IV, p. 49.

Until Duerden took up the question, only adult corallites or the young tips had been studied, the attention of paleontologists being confined to the full-grown or very young individuals. Little or no attention was devoted to the method of growth and development of the individual. While working upon the growth and development of the embryos of modern corals, Duerden turned his attention to the developmental stages preserved in fossil corals. He attempted to harmonize the young stages of these rugose corals with the methods of growth and development which he found in modern forms and cut serial sections to show the successive stages of morphological development of the individuals. As a species to study, he selected *Lophophyllum proliferum* from the Carbonic limestones, because specimens were both plentiful and well-preserved. By making thin microscopic sections transverse to the tip of the corallites, he obtained stages in development which he considered identical with those found in the early embryonic stages of hexamerous forms.[1]

In February 1906, Gordon questioned Duerden's interpretation.[2] He showed how Duerden's observations could easily be explained by an acceleration of certain septa on the basis of an original tetrameral condition, and from his own studies of young silicified specimens of *Streptelasma profundum* from the Trenton and Black River limestones showed that in the youngest stages of these geologically early forms only four primary septa occurred.

Duerden replied to this,[3] and stated that in six distinct species of rugose corals, *Streptelasma rectum* HALL, *Cyathaxonia cynodon* E. & H., *Hadrophyllum glans* (WHITE), *H. pauciradiatum* E. & H., *Microcyclus discus* MEEK and WORTHEN and *Lophophyllum proliferum* E. & H., he had found the earliest stages obtainable to have six primary septa, and therefore he considered that all rugose corals were derived from original hexamerous forms and that the four-fold condition was of secondary derivation.

In the American Journal of Science for April, 1907, the author showed that of these six species studied by Duerden, four were Devonic forms and the other two Carbonic in age. All of them, therefore, occurred very late in the geological distribution of the Rugosa. Of the four Devonic forms, three were almost disc-like and therefore were highly specialized and presented extreme difficulties, when one attempted to get at the earliest stages of growth. In case of the fourth form, *Streptelasma rectum*, HALL, he showed that a quadriseptate stage, earlier than any observed by Duerden, could be found in very perfect material, and that the secondary septa came in pair by

1 Johns Hopkins University Circular, Jan., 1902; Annals & Magazine of Natural History, May, 1902.

2 American Journal of Science, Vol. XXI, pp. 109–127, Feb., 1906.

3 Science, Aug. 24, 1906, Annals & Magazine of Natural History, Sept., 1906

pair as suggested by the earlier writers, but that the counter quadrants were accelerated in development over the cardinal quadrants and that the first pair of secondary septa appeared in the counter quadrants very early.

In the present paper, it is proposed to study a few of the rugose corals included in the Zaphrentid group both geologically in the order of their occurrence and phylogenetically in the order and mode of their development and to find, if possible, some natural order in which to group these forms systematically.

Although the Zaphrentid corals have been known for a long time, and although the representatives are very numerous and abundant and occur throughout the geological formations from early Ordovicic to the end of the Carbonic, few attempts have yet been made to trace out the ontogeny and phylogeny of their numerous genera and species.

In recent work in paleontology, certain principles and laws have come to be recognized as universal in their application. If these laws are applied in a study of the development and relationship of the genera and species of the family Zaphrentidæ, new and heretofore unsuspected truths are brought to light. Some of the apparently widely separated species of this more or less heterogeneous group are found to be very closely related, and some of the species which at first sight are very closely related really prove to be widely separated when arranged in their true relationship.

Among the most important of the principles of development which must be kept in mind when studying the phylogeny or race history of any group of living forms are these three first announced by Alpheus Hyatt.[1]

Stages in Individual Development. In the young, stages are found the equivalents of which are to be sought in the adults of ancestral types.

Acceleration in Development. "All modifications and variations in progressive series tend to appear first in the adolescent or adult stages of growth, and then tend to be inherited in successive descendants at earlier and earlier stages according to the law of acceleration, until they either become embryonic, or are crowded out of the organization, and replaced in the development by characteristics of later origin."

Morphological Equivalence. "In the different genetic series of a type derived from one ancestral stock, there is a perpetual recurrence of similar forms in similar succession, which are usually called representative and often falsely classified together, though they really belong to divergent, genetic series."

If these important principles of development are kept in mind and it is

[1] "Genesis of the Arietidæ," Smithsonian Contributions to Knowledge, 673, 1889.

also remembered that the life of any individual is a compressed and abbreviated edition of the life of the race and that in any natural classification the individual must be the unit of comparison, it will be possible to trace out the relationship and stages of development of any group, provided enough of the structure is preserved to show what the development of the individual has been.

Few groups lend themselves better to studies of this kind than the family Zaphrentidæ of the rugose corals. This is a family of wide geographical distribution and occurs throughout deposits accumulated through long periods of geological time. In the majority of the genera and species, the individuals are solitary and have grown in free and open space and are not marred or distorted by crowding or the presence of other forms. The nature of the coral skeleton is such that all stages of development are recorded from the time the little polyp embryo secrets its first calcareous support till the polyp finally dies and its full-grown calyx or cup becomes buried in the surrounding mud. Many of the fossil corallites are so perfectly preserved that even the youngest stages can be found and studied, and it is upon studies of this nature that the following paper is based.

In the course of these studies, three methods of treating the material were pursued, according to its nature and abundance, the method of fossilization and the object in view in studying the particular specimen:

1. *Treating with acid.*—Silicified specimens in a calcareous or limestone matrix were treated with acid. This method was particularly useful in preparing the specimens of *Streptelasma profundum* from the Black River and Trenton limestones.

2. *The making of microscopic sections through the corallite.*—In the course of these studies many microscopic sections of corals were cut. This method furnished a permanent record of all stages observed, but it was impossible to cut the sections thin enough to preserve all the stages in development. Sections of the earliest stages were extremely difficult to make, and even when made could rarely be ground thin enough to show anything distinctly.

3. *Grinding from the tip of the corallite and observing and sketching each successive step in development.*[1] This proved to be the most satisfactory method of following the developmental stages. Its great drawback lies in the fact that each stage must be destroyed before the next stage can be seen, the only permanent records being the sketches made and observations noted during the grinding.

[1] This method was first described in print by Duerden, but it was used by the author before Duerden's publication.

The paleontological collections of Columbia University are particularly well supplied with material of the Streptelasma and Zaphrentid groups, and this material was placed at my disposal. The particular species studied will first be described in geological order, and these descriptions will be followed by a discussion of the principles involved.

The study of coral morphology has been hampered and confused by the duplication of terms and ambiguity of expressions used in referring to certain parts or features of the coral structure. Among the multitude of names and terms used for the different parts of the coral structure, it is not always easy to determine which is the best or which is correct according to precedence of application. The following is a partial list of the terms used in these studies with explanations of their meanings.

Corallite — the complete hard part or skeleton of an individual coral.

Calyx — the cup-like upper or larger end of the corallite.

Septum — a more or less radially placed upright thin laminar partition in the corallite.

Carinæ — well-marked vertical or curving cross bars on the sides of the septa.

Dissepiments — horizontal plate-like structures which bridge across between the septa.

Tabulæ.— well-developed dissepiments which bridge across the entire calyx.

Primary septa — the four first-formed septa which divide the corallite into four quadrants in which the four sets of later septa are developed. They are the cardinal septum, the counter septum and the two alar septa. The cardinal septum is located at the ventral or anterior end of the median axis of the corallite, and the counter septum at the dorsal or posterior end. The alar septa are located one on either side of this median axis.

Fossula — a depression or furrow surrounding the cardinal septum; also frequently applied, though incorrectly, to the depression or furrow between the alar septa and the septa of the counter quadrants. This is called pseudofossula by Grabau in his "North American Index Fossils."

Secondary septa — the later developed prominent septa which either reach or almost reach the center of the calyx.

Tertiary septa — small septa arising in the interseptal spaces between the septa of the primary and secondary cycles. In the geologically earlier forms these project freely into the calyx throughout their length. In the later forms they are attached by their inner margin to the primary or secondary septum immediately dorsal to them.

Pseudocolumella — the pillar-like structure in the center of the corallite formed by the inner margins of the primary and secondary septa either uniting or partly uniting near the center of the calyx.

II. Ordovicic and Siluric Corals.

In the limestones of the middle Ordovicic the earliest representatives of the rugose corals are found in North America. No individuals of this group have yet been found in the Cambric deposits, and those found in the middle Ordovicic are quite primitive and simple in their organization and development. They are taken as the earliest representative forms obtainable.

Streptelasma profundum (*Owen*).

1844 *Cyathophyllum profundum* Owen, Geological Explorations of Iowa, Wisconsin, and Illinois pl. XVI, fig. 5.
1847 *Streptelasma profunda* Hall, Palæontology of New York, vol. I, p. 49, pl. XII, figs. 4a–d.
1863 *Petraia profunda* Billings, Geology of Canada, p. 938.
1891 *Streptelasma profundum* Winchell and Schuchert, Minnesota Geological and Natural History Survey, Final Report, vol. III, part I, p. 88, pl. G, figs. 17–19.

This species is the earliest representative of the genus Streptelasma in this country. It is found quite abundantly in the Chazy (Birdseye), Black River and Trenton limestones in the central and eastern parts of New York and in Canada. This is a small species, and in his publication cited above Hall describes it thus:

Obliquely turbinate, often slightly curved near the base, expanding above more or less abruptly; cell profoundly deep, extending nearly to the base of the coral; margin of the cup reflexed; surface scarcely marked by transverse rugæ; lamellæ from 36 to 60, strong, nearly equal on the margin, but distinctly alternating in length within; no transverse dissepiments or celluliferous structure.

Although this species is frequently referred to in geological and paleontological literature, no complete and exhaustive study of its structure and development has ever been made. This is undoubtedly the most primitive representative of the genus Streptelasma. It is not only the earliest in its geological distribution but also the simplest in its structure and development.

In 1906, Gordon called attention to the primitive character of *Streptelasma profundum* in his paper entitled "Studies on Early Stages in Paleozoic Corals."[1] His studies were made on a few young silicified individuals

[1] American Journal Science, Feb., 1906, pp. 123–4 and fig. 16.

from the Black River limestone, and he has given a very good diagrammatic drawing of one of these individuals, showing it as if it were cut along the counter septum and unrolled or flattened out. I have examined the specimens studied by Gordon and numerous others in the paleontological collections of Columbia University. They are all silicified specimens found in the Black River limestone at Georgian Bay, Limestone Island, from which the calcareous matrix has been removed by acid. Many of the specimens were very small and therefore very young individuals. The septa of these young individuals were not developed to a sufficient extent to unite in the middle of the calyx. As a result of this, one can see the whole structure of the individual and can note the development of the septa relative to one another and can compare their size and length. In all of these individuals, the tip or youngest stage of the calyx is lacking in septa. The first septa to appear in the base of the calyx or cup are the four primary septa; the cardinal, two alar and counter septa. In some of the very smallest specimens a millimeter or less in diameter and from one to two millimeters long there were no septa present, the calyx consisting only of a smooth hollow cone, sometimes straight and sometimes slightly curved or twisted.

The question now arises as to what this absence of septa in the youngest individuals may mean. Three possible explanations are suggested:

1. Silicification was imperfect, and the septa in the earliest stage were not replaced and preserved in the silicified specimen;
2. Resorption may have taken place during the growth of the young individual,[2] thus leaving no septa at this stage to be preserved.
3. In its earliest stages this coral may have had no septa, its skeleton consisting only of a cone-like structure surrounding the polyp.

It is hard to understand how imperfect silicification can be relied upon to explain the absence of septa in the youngest stages of these corals when the delicate edges of the septa in the later stages are uniformly well preserved. This condition could easily be explained by the theory of resorption of the earliest parts of the septa, but this is very doubtful as resorption has not been noted in corals, and it seems more likely that in the earliest stages no septa were present. A persistence into the adult stage of this embryonic or earliest septa-less condition might easily explain the origin of such a genus as *Cystiphyllum*, which never develops septa.

After the four primary septa appear, secondary septa are added in all four quadrants. In this species the first pair of secondary septa in the counter quadrants and the first pair in the cardinal quadrants are apparently added simultaneously, whereas in the geologically later species of the *Strep-*

[2] See GORDON *op. cit.* p. 124.

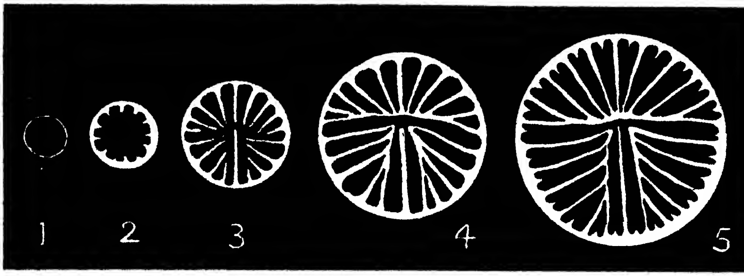
telasma group, the first pair of septa in the counter quadrants are invariably added before the first pair in the cardinal quadrants.

After finding that the first pair of secondary septa appeared almost simultaneously in the counter and cardinal quadrants, the question arose as to whether the later pairs of secondary septa were added simultaneously or if, during the later development of the individual, the counter quadrants were accelerated over the cardinal, and the same condition existed in the mature individuals as was found in corallites of other species from higher geological horizons. Fourteen of the most perfect individuals obtainable were carefully studied and the number of septa in each quadrant counted. These individuals were from three or four millimeters up to twelve or fifteen millimeters in diameter across the cup and, varying according to size, had from three to eight secondary septa in each quadrant. Of these fourteen individuals, eleven had the same number of pairs of septa in the counter as in the cardinal quadrants. In the majority of these, the pairs of septa seemed to have appeared almost simultaneously in the counter and cardinal quadrants. In one or two individuals the cardinal quadrants seemed to be slightly in advance of the counter quadrants, and in three or four the counter quadrants were distinctly in advance of the cardinal quadrants, although the number of septa present were the same in each. The remaining three of the fourteen individuals have one pair more of secondary septa in the counter quadrants than in the cardinal quadrants. Thus it is seen that on an average the secondary septa appear almost simultaneously, but that the counter quadrants are just a trifle in advance of the cardinal quadrants. The smaller tertiary septa appear in the later stages and so far as can be observed arise in exactly the same order as the secondary septa, each one taking its place between two already existing septa of the primary or secondary cycle.

This appearance of the pairs of secondary septa simultaneously in the counter and cardinal quadrants is a decisive argument in favor of the original tetrameral primary condition. If, for the sake of argument, we call the pair of septa occurring one on either side of the counter septum primary septa, as Duerden and Carruthers [1] have recently insisted that we should do, we are confronted with the anomalous condition of having only three of the fourteen individuals of *Streptelasma profundum* above considered with the same number of secondary septa in the counter as in the cardinal quadrants, and the other eleven individuals would have one more pair of secondary septa in the cardinal quadrants than in the counter, a condition exactly opposite to that found in any other species of rugose coral. Therefore, it seems incorrect to consider any but the first four as primary septa. To

[1] R. C. CARRUTHERS: Annals and Magazine of Natural History, Nov., 1906, pp. 356–368.

interpret this species as having four primary septa and bilateral pairs of secondary septa added simultaneously or almost simultaneously in the counter and cardinal quadrants, allows *Streptelasma profundum* to fall in line with all the other species of this and allied genera. The interpretation



Figs. 1–5. *Streptelasma profundum.* × 4.

of it as an original hexamerous form would make it an anomaly that will not bear comparison with other rugose corals.

In the adult corallite of *Streptelasma profundum* a condition is found that is characteristic of the developmental stages of other later species. Only a few of the septa reach the center. The others extend down the interior of the cup, those in the counter quadrants in a direction as if they would run into and unite with the dorsal side of the alar septa, and those in the cardinal quadrants as if they would unite with the cardinal septum on either side. But instead of reaching and uniting with the primary septa, the inner margins of the secondary septa are bent so that they unite, each one respectively with the secondary septum immediately preceding it in the order of appearance and dorsal to it in position in the corallite. This gives, when looking down into the cup, the condition shown in figure 6. All the secondary septa are united in a pinnate manner by their inner margins and leave a well-defined open space along either side of the cardinal septum and a space on the dorsal side of each alar septum.

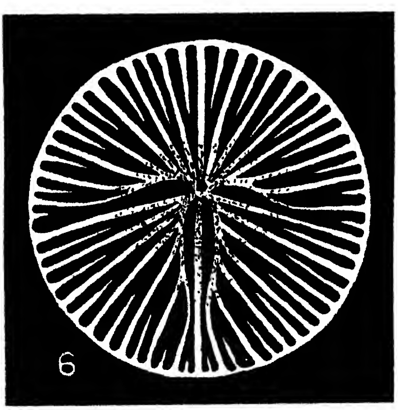


Fig. 6. *Streptelasma profundum.* × 4.

In so far as can be observed in the surface views the tertiary septa appear

in the interseptal spaces in the same order as the secondary septa. They remain short and free throughout their length. They never appear to be attached by their inner margins to the adjacent secondary septa, as is the case in many species occurring in geologically higher horizons.

Figures 1–5 represent five sectional views of five different individuals of different sizes and ages showing the different stages in development described above. Figure 1 has no septa. Figure 2 has the four primary septa and two pairs of secondary septa in the counter and cardinal quadrants. In figure 3, the secondary septa reach almost across the calyx, and in figure 4 they are similar in arrangement to the adult shown in figure 6, while figure 5 shows the first appearance of tertiary septa.

In the limestones of the upper Ordovicic, particularly in the Cincinnati Group, are found an abundance of rugose corals which represent an advance in the Streptelasma development. The most prominent among these are *Streptelasma corniculum* and *Streptelasma rusticum*.

Streptelasma corniculum *Hall.*

1847 *Streptelasma cornicula* HALL, Palæontology of New York, vol. I, p. 69, pl. XXV, 1a–e.

1863 *Petraia corniculum*, BILLINGS, Geology of Canada, p. 156, 938.

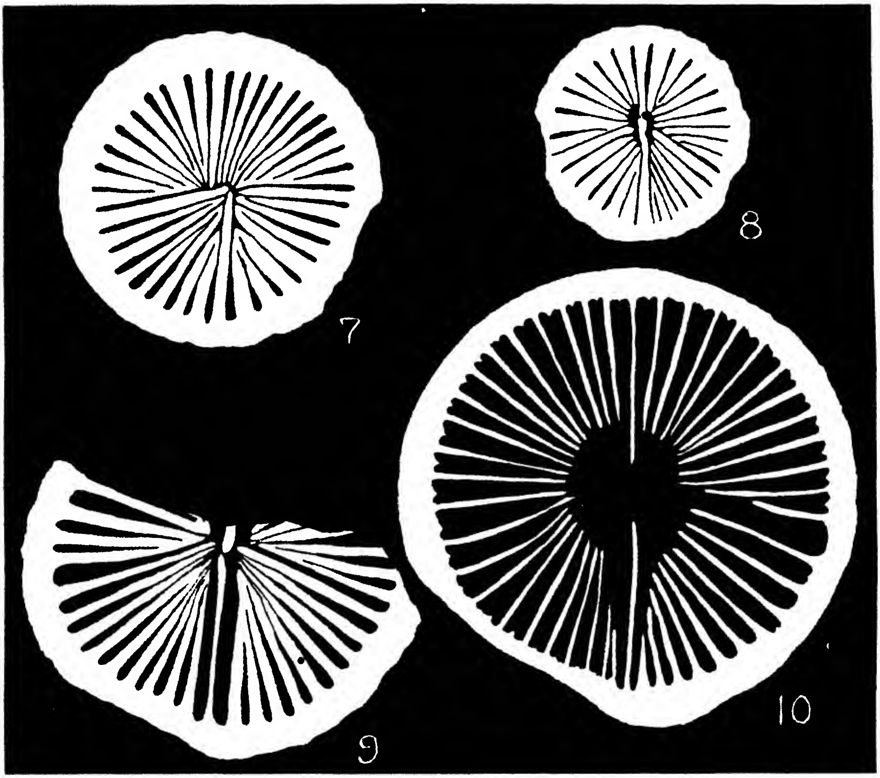
1875 *Streptelasma cornicula* NICHOLSON, Paleontology of Ohio, vol. II, p. 218.

This species, which occurs abundantly in the Trenton and Cincinnati limestones, is larger and more robust in growth than *S. profundum*. Hall (*loc. cit.*) describes it thus:

> Turbinate, curved near the base, which terminates in an acute point, somewhat rapidly expanding above; cup profound; lamellæ about sixty; surface marked by strong longitudinal lines indicating the lamellæ, which are crossed by fine concentric wrinkled lines. Length varying from three-fourths to one and one-half inches.

The septa in this species are more numerous, and in the later stages of growth are more nearly radially placed. The accompanying illustrations, figures 7–10, show characteristic stages in the individual development of the corals of this species. These are drawn from thin sections cut from a typical specimen. In figure 7, a section taken quite close to the tip of the coral, a condition is seen similar to the adult stage in *S. profundum*. The four primary septa are largest and most prominent, and the secondary septa are distinctly grouped in quadrants. Figure 8, at a later stage, shows a very similar arrangement. The secondary septa are more numerous, and more of them reach the center. In these two stages the septa are very thick,

practically filling the whole interior of the corallite. Figure 9, from a still later stage, shows the septa more fully developed and more nearly radially placed. The septa at this stage are not as thick, and the interspetal spaces are larger and more open. In figures 8 and 9, the tertiary septa are indicated by the centers of calcification, but they do not project beyond the wall into the calyx. Figure 10 is from a section taken so that it shows in its center the base of the open cup. Even at this late stage of the individual develop-



Figs. 7–10. *Streptelasma corniculum.* × 4.

ment the great prominence of the four primary septa is distinctly shown. The tertiary septa have also appeared projecting beyond the wall, one between each fully developed septum of the primary and secondary cycles. In no case do the septa meet and unite in the center to form a pseudocolumella. After they are fully developed, they are apparently free at the center. Until fully developed, the inner margin is frequently attached to the ventral side of the next preceding septum.

From this study of the species it is seen that *Streptelasma corniculum* can easily be derived from the *S. profundum* type. The principal differences lie in its larger size, more robust growth, larger number of septa corresponding with the increase in size and more nearly radial arrangement of the septa. Another fact to be noted is that the counter quadrants are accelerated in development over the cardinal quadrants, there being at least three more pairs of septa in the counter quadrants than in the cardinal.

Streptelasma rusticum *Billings.*

1851 *Streptelasma corniculum* EDWARDS & HAIME, Mon. Poly. Foss. des Terr. Pal., pl. 7, fig. 4.
1858 *Petraia rustica* BILLINGS, Geol. Sur. Canada. Report of Progress, 1857, p. 168.
1875 *Streptelasma cornicula* NICHOLSON, Pal. Ohio, vol. II, p. 218.
1882 *Streptelasma rusticum* HALL, 11th. Rept. State Geol. Ind., p. 376, pl. 51, figs. 2–4.
1891 *Streptelasma rusticum* WINCHELL and SCHUCHERT, Geol. & Nat. Hist. Sur. Minn., vol. III, p. 93.

This species, throughout the earlier stages of its development, is identical with *S. corniculum.* It, however, attains a much larger size, and in the later stages of development becomes almost cylindrical in manner of growth. Winchell and Schuchert were probably the first to point out that a line of development could clearly be traced in *S. profundum, S. corniculum* and *S. rusticum.*[1]

Enterolasma caliculum *Hall.*

1852 *Streptelasma calicula* HALL, Palæontology of New York, vol. II, pl. 32, fig. 1a–k.
1900 *Enterolasma caliculum* SIMPSON, Bull. 39. New York State Museum, p. 203–205.

Throughout the Siluric, although individuals are very numerous, the number of species representing the Streptelasma line of development is very limited, *Enterolasma caliculum* being the only really important one in this whole period.

Enterolasma is a genus proposed by Simpson in 1900 (*loc. cit.*) for certain species previously included in the genus Streptelasma. The feature on which the generic distinction was based was the presence of a peculiar pseudocolumella. The author's generic description is as follows:

[1] Geol. & Nat. Hist., Sur. Minn., vol. III, pt. I, p. 87.

Corallum moderately small, cylindro-conical, usually straight, but sometimes slightly curved; calyx circular, moderately deep, sides thin; septal fovea obscure and in some species apparently obsolete; septa alternating in size, the larger ones continuing nearly to the center, having projections from their extremities which continue to the center, becoming much involved, forming a pseudocolumella of very peculiar appearance, somewhat resembling the convolutions of the intestines; sides of the septa with numerous papillate elevations or carinæ, which in a transverse section give to the septa a crenulate or echinate appearance; tabulæ and dissepiments present. The characteristic feature of this genus is the peculiar appearance of the pseudo-columella.

Simpson lists as one of the species of this genus *Streptelasma caliculum* Hall, and the generic description applies in all but one particular. *Enterolasma caliculum* does not have "papillate elevations or carinæ" on the sides of the septa. Instead, the cross section shows the septa to be smooth and straight until they become involved in the peculiar pseudocolumella. In the individual studied, although the septa are somewhat irregular at the center, they do not seem to have projections forming the peculiar pseudocolumella described above. It appears rather that the pseudocolumella is incomplete or imperfectly formed, and under certain circumstances gives this peculiar appearance from which Simpson gives the name Enterolasma.

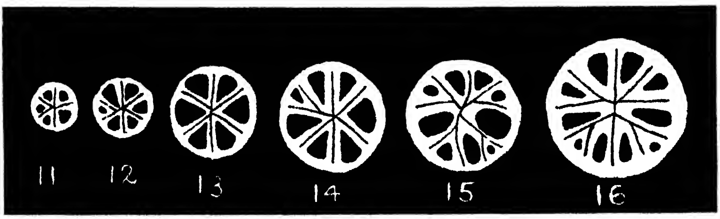
Enterolasma caliculum is described by Hall as follows:

Turbinate, oblique or curved, more or less rapidly expanding by the addition of interstitial rays; cup moderately deep; rays or vertical lamellæ about half the thickness of the space between them, from 20 to 50, ordinarily about half this number, more or less curved toward the center; external surface with the lamellæ very distinct and marked by transverse striæ; surface rarely corrugated; rays alternating with short dentations on the inner margin of the cup (*loc. cit.*).

This species occurs throughout the middle Siluric but is found most abundantly in the upper part of the Clinton beds and in the Rochester Shale. It is a coral well adapted for the study of its ontogeny in all except the very youngest stages. Perfect tips are hard to obtain; nevertheless, a very young stage has been found, and all stages of development from this to the adult have been carefully traced.

A small individual of this species was obtained from the matrix about a larger individual. The stages of development observed in this very small specimen are shown in figures 11–16. The fractured end, as it was when removed from the matrix, showed five septa (figure 11). After grinding a little a sixth septum appeared (figure 12). The cardinal, counter and alar septa were located by the arrangement of the costæ or external ridges of the

calyx. The individual corallites of this species are, as a rule, so perfect and symmetrical, and the costæ on the exterior show so clearly that there can be no doubt about the orientation of the individuals and identification of the septa. This sixth septum comes in between the counter and alar and at first extends only from the wall to the dorsal side of the alar septum. As it becomes more and more fully developed the point of apparent union of this septum moves along the dorsal side of the alar septum until it becomes radially situated (figure 13). The individuals of this species develop very rapidly in their early stages, and a very small amount of grinding off at the tip brings out the successive developmental stages. A little further grinding showed



Figs. 11–16. *Enterolasma caliculum.* (Enlarged.)

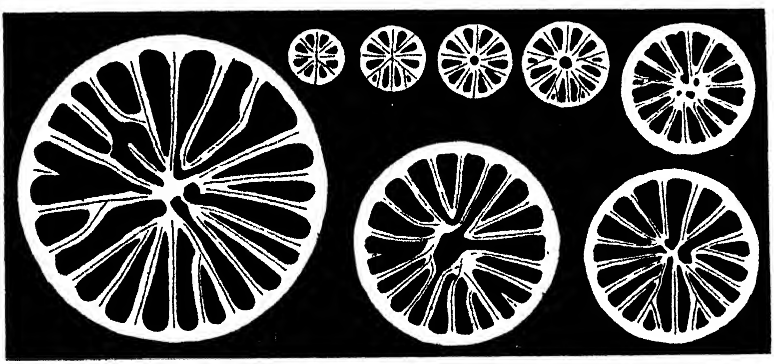
another secondary septum beginning to appear in one counter quadrant (figure 14), and still further grinding showed a corresponding septum in the other counter quadrant, and at the same time a secondary septum began to arise in one cardinal quadrant (figure 15). This cardinal quadrant septum came in as a short septum extending from the wall of the calyx to the ventral surface of the alar septum, and as it developed, the apparent point of attachment of the inner margin moved inward toward the center of the calyx. The next stage in the development shows two secondary septa in each counter quadrant and one in each cardinal quadrant (figure 16).

As this individual was very small, the later stages of development could not be followed in it, but another individual was found showing eight septa on the fractured tip (figure 17) and the successive stages in the development of this were followed until the corallite reached a diameter of 8 mm.

In the fractured tip of this individual, eight septa are present, and according to their relation to the costæ on the exterior of the calyx these are interpreted as the cardinal, counter, two alar and two secondary septa in each counter quadrant. Grinding it down to the next stage (figure 18), a pair of secondary septa arise in the cardinal quadrants. These are short at first and apparently united with the ventral side of the alar septa. As they develop, the point of apparent attachment moves in till they become approxi-

mately radially placed as is shown in figure 19. In this same stage the pseudocolumella formed by the union of the inner edges of the septa is seen to have an opening in it. In figure 20, two additional pairs of secondary septa have appeared, one in the counter and one in the cardinal quadrants. A single opening is still present in the pseudocolumella. In the stage represented in figure 21, all the septa present in figure 20 have become nearly radially placed and a fourth secondary septum appears in one of the counter quadrants. The pseudocolumella here shows four distinct openings, one of which communicates with one of the interseptal spaces.

In figure 22, a fourth secondary septum is well developed and reaches to the center in each counter quadrant, and a third secondary septum has started in each cardinal quadrant. The pseudocolumella can no longer be recognized as such. The inner margins of all the fully developed septa



Figs. 17–24. *Enterolasma caliculum.* × 5.

are now irregularly united. In figure 23, the continuity of some of the septa is broken, and the arrangement is irregular, while in figure 24, both of these characters are carried still farther, and at the same time the number of septa has been increased until now there are five secondary septa in each counter quadrant and four in each cardinal quadrant. The actual dimensions of the sections figured in figs. 17–24 are as follows: 17, 1.5 mm.; 18, 1.8 mm.; 19, 2.0 mm.; 20, 2.3 mm.; 21, 3.5 mm.; 22, 4.5 mm.; 23, 5.5 mm.; and 24, 8.0 mm.

Other stages of the development of this species are shown in figures 25 and 26. These were made and the septa identified in the following manner: The cardinal and alar septa were located by the arrangement of the costæ on the exterior of the corallite. Then a fine India ink line was drawn down the side of the corallite, marking the positions of these three principal septa.

The top of the calyx was ground smooth and polished. A dot of ink was placed on this polished surface right at the end of each of the ink lines on the side of the corallite. These three dots marked the upper exposed end of the three principle septa. The corallite was then cemented by this polished surface to a piece of plate glass and sawed off as close as possible to the glass. The thin slice cemented to the plate glass was ground down, transferred and mounted as a transparent microscopic section, the dots of ink all the while marking the identity of the three principle septa and being unaffected by the heat and substance used in cementing and mounting. The process

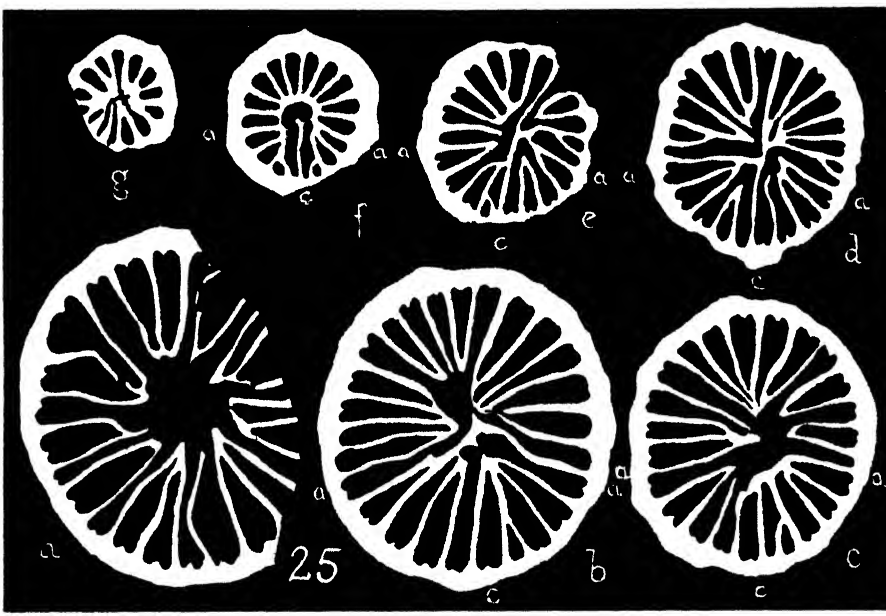


Fig. 25a–g. *Enterolasma caliculum.* (Enlarged.)

was repeated as often as possible, and as many sections as could be made were cut from a single corallite. Figures 25 and 26 show seven sections each made from two individuals in this manner. In the first and last section of each, the principle septa were not identified. The intermediate stages, however, are well shown. In these microscopic sections, a permanent record is preserved of all observations made, but the development cannot be followed step by step through all its minutest details as it was by the process of grinding down from the tip and sketching each step as it was encountered, at the same time destroying one stage in order to get the next.

Figure 26 a is a section from the open calyx of the corallite. Here the septa are all short and about equal in length, and project freely into the cup. Small tertiary septa alternate with all the primary and secondary septa. Figure 26 b is from the corallite just below the open cup. In it there are present the four primary septa, four pairs of secondary septa in each cardinal quadrant and seven pairs of secondary septa in each counter quadrant. Small tertiary septa are present and alternate with all the primary and secondary septa. Figures 26 c–g show other stages in the development already described. Figures 26 c, d and e show very well the irregular method of grouping or uniting of the inner edges of the secondary septa to form the peculiar pseudocolumella. Figure 25 shows similar stages from another individual.

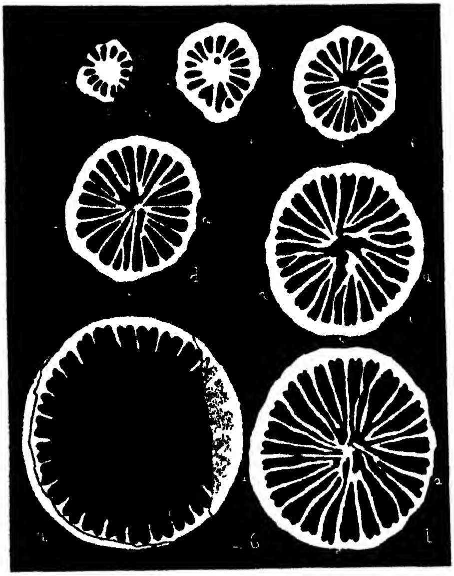


Fig. 26. *Enterolasma caliculum.*

A study of the developmental stages of these individuals shows that throughout the counter quadrants are in advance of the cardinal quadrants, and this feature becomes more pronounced in the later stages of development. In the earliest stages obtained, one pair of secondary septa have appeared in the counter quadrants, and two pair appear in these quadrants before the first pair arise in the cardinal quadrants. Up till the time when the fourth and last pair of septa are developed in the cardinal quadrants, the number of septa in the counter quadrants is just one more than in the cardinal quadrants. After all the septa are developed in the cardinal quadrants, two more pairs appear in the counter quadrants, making seven pairs of secondary septa in the counter quadrants as compared with four pairs in the cardinal quadrants. Thus it is seen that the acceleration in development of the counter quadrants progressively increases in the life of the individual and is very strongly marked in the later stages. (Compare stages in *Stereolasma rectum* Hall from the Devonic.)

[Zaphrentis] racinensis *Whitfield.*

1882 *Zaphrentis racinensis* WHITFIELD, Geology of Wisconsin, vol. IV, p. 277, pl. XIV, figs. 1 and 2.

Whitefield describes this species in the following words:

Corallum forming a short, rapidly expanding, cup-shaped or turbinate body, nearly as wide as high, and strongly curved; calyx occupying nearly the entire depth of the body; the floor, in a specimen measuring one and one-quarter inches in diameter, not exceeding three-eighths of an inch in width; longitudinal or vertical lamellæ moderately well developed, but very thin and distinctly alternating in size, increasing in number only along the primaries dividing the dorsal and lateral sections; those of the two sections on the inner side of the curvature are more numerous than the others, counting ten in each division, while those of the outer divisions are only eight on each side, making, to the entire cup, thirty-six primary lamellæ on the specimen figured; fosset deep, situated on the outer side of the curvature, very narrow and having only one primary lamella depressed within the cavity.

The examples of the species observed are all internal casts of the cup, but are well marked and quite numerous. They present evidence of the outer surface having been transversely wrinkled, which, owing to the thinness of the-substance, have shown in the cup and been preserved on the cast of the interior.

This species is found in the Niagara beds at Racine, Wis., and although represented only by internal moulds it is evidently derived from the Streptelasma stem and has reached about the same stage of development as *Enterolasma caliculum*, although in a different direction and along an independent line.

In all probability, this is not a true *Zaphrentis* but belongs to a different genetic series, which in the Devonic gives rise to the genus *Heterophrentis* of Billings and in the upper Siluric beds gives rise to the genus *Heliophrentis* of Grabau which leads up to the terminal form *Heliophrentis corniculum* by a development parallel with that of the *Heliophyllum* line in the Devonic. As in *Heliophyllum*, this Heliophrentis line of development is characterized by the gradual addition of carinæ on the sides of the septa.

III. Devonic Corals.

Throughout the deposits of the Lower and Middle Devonic the rugose corals are widely and abundantly distributed. In the lower beds are found forms very closely related to those of the Upper Siluric. In the middle beds the forms become more diversified, and in the upper beds they plainly show that they have passed the acme of development and are on the decline.

Enterolasma strictum *Hall.*

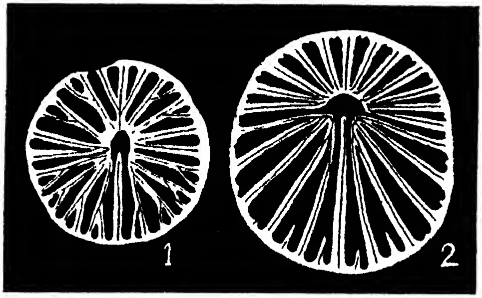
1874 *Streptelasma (Petraia) stricta* Hall, 26th Report New York State Museum, p. 114.
1879 *Streptelasma (Petraia) stricta* Hall, 32d Report New York State Museum, p. 142.
1883 *Streptelasma strictum* Hall, Report of the New York State Geologist for 1882, pl. I, figs. 1–10.
1887 *Streptelasma strictum* Hall, Palæontology of New York, vol. VI, pl. I, figs. 1–10.
1897 *Streptelasma strictum* Girty, 14th. Annual Report New York State Geologist. (1894) p. 300.
1900 *Enterolasma strictum* Simpson, Bull. 39, New York State Museum, p. 203.

This species is abundant in the limestones of the Lower Devonic, particularly in the New Scotland beds. In the Twenty-sixth Annual Report of the New York State Museum, Hall describes it thus:

> Cup narrowly turbinate, very gradually and regularly enlarging at an angle of about 30 degrees, straight or slightly curved except the small apex which is sometimes more abruptly bent. Exterior surface strongly and distinctly ribbed longitudinally and marked with concentric, unequal undulations of growth; longitudinal ribs rounded, from forty-five to fifty-five on specimens at the point where the diameter is half an inch; the increase of ribs or rays taking place usually at three points, but sometimes only at two points. Interior of cup broad and deep, with thin sharp margin; the lamellæ not projecting into the cup until near the bottom, but forming low rounded rays, a little stronger than those on the exterior.
>
> The primary lamellæ are smooth on the edge, and strongly granulose on the sides below, and sometimes more or less twisted in their direction to the center, although generally direct; uniting and coalescing near the middle, forming an indistinct plate or vesiculose core, from an eighth to three-sixteenths of an inch in diameter; and in vertical section, sometimes showing an indistinctly defined vertical wall.
>
> The secondary lamellæ strongly denticulate on the edge below the surface of the other lamellæ. Fossette obscure or obsolete.
>
> This species is distinguished by the rigid straightness of its form, the strongly ribbed exterior and the deep wide cup with undeveloped rays or ribs; and in these characters differs from both those of the Niagara group and also from those in the higher formations.

In the Palæontology of New York, vol. VI, p. 1, Hall gives a similar description of this species with one additional observation. In that description he states that ". . . . alternate lamellæ extending only a short distance from the walls at the base of the calyx and frequently coalescing with the primary lamellæ" are a characteristic of this species. The statement concerning the increase of lamellæ in this species sometimes taking place at only two points is evidently an error, for in this respect the species does not differ from other Streptelasma forms.

Silicified specimens of *Enterolasma strictum* are very abundant in the New Scotland limestone, but they are not sufficiently well preserved to use in grinding, or in cutting sections. Numerous specimens of various sizes and ages have been carefully studied. The general manner of development is found to agree with that observed in the Ordovicic and Siluric corals. The septa unite at the center more distinctly than in any of the preceding species. The pseudocolumella thus formed is not exactly solid, but it is much more substantial than that found in *Enterolasma caliculum*. In many specimens when looked at from the top it appears to be hollow or approaching in appearance the well-developed inner wall of such a species as *Hapsiphyllum varsoviense*. Another feature in which this species differs from those discussed in the previous chapter is in the manner of development of the small tertiary septa. In all the geologically earlier species the tertiary septa (secondary lamellæ of Hall) arise as low, free ridges between adjacent primary and secondary septa. They remain free and unattached to any of the primary or secondary septa throughout their development. In *Enterolasma strictum* a different condition is found. This condition is mentioned by Hall when he states that the alternate septa frequently coalesce with the primary septa, and is clearly shown in the sectional views of figures 1 and 2. Of these two views figure 2 is taken just below the base of the cup, while figure 1 is taken farther down in the corallite.



Figs. 1–2. *Enterolasma strictum.* × 4.

This species was taken by Simpson as the type of his genus *Enterolasma*.[1] In the large number of specimens from the New Scotland limestone beds examined in the present study only one presented the appearance in the figure by Simpson accompanying his generic description of *Enterolasma* and this was a large individual considerably above the average size. The specimens examined ranged from 5 mm. to 25 mm. in length, and all, with the single exception above noted, agreed with Hall's description and the accompanying figures. All of these specimens, however, were silicified and not adapted to be used for either serial or longitudinal sections. Therefore instead of taking serial sections from one individual to get the changes in

[1] Bull. 39, N. Y. State Museum, pp. 203–205, 1900.

development, the interior views of several individuals ranging from relatively small to large size have been studied.

Stereolasma rectum *Hall.*

1843 *Strombodes? rectus* Hall, Geol. Report 4th. District of New York, p. 209, fig. 5.
1851 *Cyathophyllum rectum* Edw. & H. Polyp. Foss. des Terr. Pal.
1876 *Streptelasma recta* Hall, Illustrations of Devonian Fossils, pl. XIX, figs. 1–13.
1900 *Stereolasma rectum* Simpson, Bull. 39, N. Y. State Mus. pp. 205–206.

Hall describes the species thus (*loc. cit.*):

General form turbinate, elongated, gradually expanding from the base; straight; surface marked by longitudinal lines, which indicate the internal laminæ.

This is an abundant fossil, sometimes appearing in pairs, but never joined together. It usually tapers gradually to a very small point at the base. The cup is very deep and the margins thin, being usually flattened.

In 1900, Simpson used this species as the type of his genus Stereolasma which he describes thus:

Corallum varying in size, straight or curved, simple; calyx circular: septal fovea conspicuous; septa alternating in size, the larger ones continuing to the center, straight or very slightly twisted; between the septa at the center of the corallum a deposit of stereoplasma, which has the appearance of a columella; tabulæ and dissepiments frequent. The pseudocolumella distinguishes this genus from Zaphrentis.

It may be added that the presence of this pseudocolumella also distinguishes *Stereolasma* from *Enterolasma* and is the characteristic feature of the Stereolasma stage of the Streptelasma development.

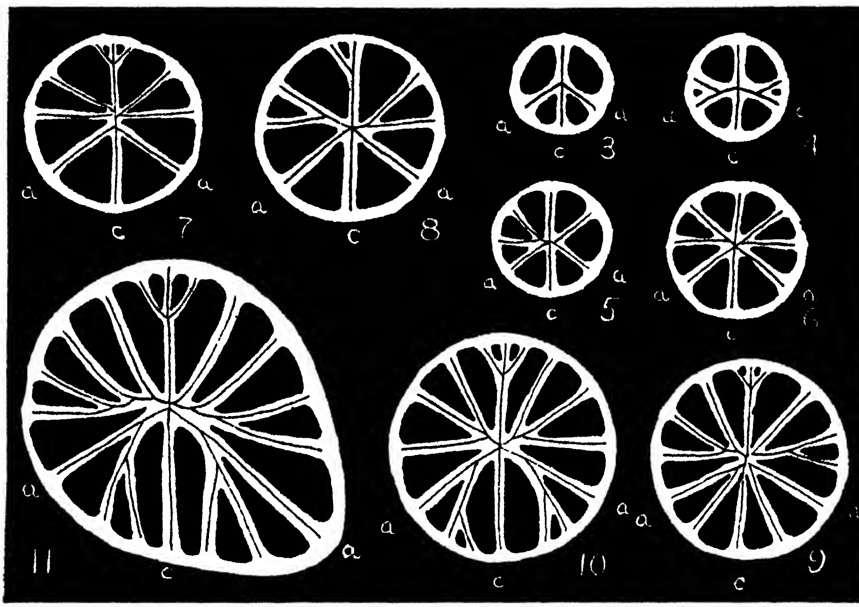
This species is very abundant in the Hamilton shales of the upper Devonic, and perfectly preserved specimens can easily be obtained. It is a particularly interesting species for these studies because it is one of the species reported by Duerden to have six primary septa in the youngest stage and to develop the four-fold structure later.[1]

The collections in the paleontological laboratory of Columbia University are particularly rich in this species, and from some two or three hundred corallites I selected the most perfect individuals for this investigation. Some of these were found with perfect tips and some with the ends slightly fractured. Following the method described in the first chapter of this

[1] Annals and Magazine of Natural History, series 7, vol. XVIII, p. 236, Sept., 1906. The Morphology of the Madreporaria. The Primary Septa of the Rugosa.

article, an individual corallite held by the large calycular end was ground off at the tip very gradually on a plate of glass with fine emery, and each successive stage of development was carefully noted and sketched. These successive stages are enlarged and shown in the accompanying figures. These figures, with the exception of figures 3 and 7, are the successive stages in the development of a single individual.[1]

Figure 3 shows the tip of an individual with only the four primary septa present. These septa, however, are not disposed at right angles. The



Figs. 3–11. *Stereolasma rectum*. (Enlarged.)

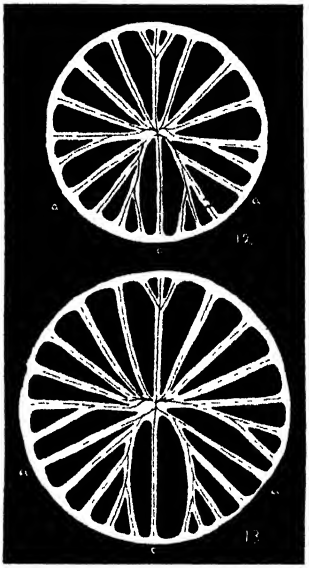
alar septa are inclined toward the cardinal, thus leaving the counter quadrant spaces considerably larger than the cardinal quadrant spaces.

Figure 4 shows the slightly fractured tip, the first view of the individual which was followed throughout its stages of development. Here the four primary septa are present, and two secondary septa have appeared, one in either counter quadrant. These are distinctly not equal to the primary septa and are not radially placed, but are short and are joined by their inner border to the dorsal side of the alar septa. As they develop, this point of

[1] Figs. 3–16 are reproduced from a former article by the author on this species printed in the American Journal of Science for April, 1907.

attachment moves inward until they, in some individuals, become equal in size with the primary septa and are radially arranged. There are in the Columbia collections individuals which show gradations from the conditions shown in figure 4 to six equal and radially disposed septa.

Figure 5 shows the appearance of a second secondary septum in one counter quadrant. Figure 6 shows two secondary septa in each counter quadrant. Figure 7 is the same stage from another individual and shows that a pair of tertiary septa have already appeared, one on either side of the counter septum. Attention is especially called to this very early appearance of the first pair of tertiary septa adjacent to the counter septum. Figure 8 shows the appearance of the third secondary septum in one counter quadrant and the appearance of a tertiary septum in the same quadrant. In figure 9 we see a tertiary septum present on either side of the counter septum, three secondary septa in either counter quadrant, and one secondary septum in each cardinal quadrant. In figure 10, two secondary septa have appeared in each cardinal quadrant, and in figure 11 four are present in each counter quadrant. In figure 12, there are three in each cardinal quadrant and five in each counter quadrant. Figure 13 has four secondary septa in each cardinal quadrant and six in each counter quadrant. Attention is called to the grouping of the septa in this and the preceding figures. Each successive septum to appear in each quadrant respectively is attached by its inner border to the side of the previous septum, giving in this stage an arrangement of the septa similar to the adult condition in *Streptelasma profundum*, of the progressive series at a very much earlier geological time, and also of the adult condition of the genus *Hadrophyllum*, a retrogressive genus occurring late in the geological history of the rugose corals.[1] Figure 14 has the same number of secondary septa but they are more fully developed and in addition three more pairs of tertiary septa have been added in the counter quadrants and two pairs have appeared in the cardinal quadrants. In figure 15, a seventh pair of secondary septa have appeared in the counter quadrants,

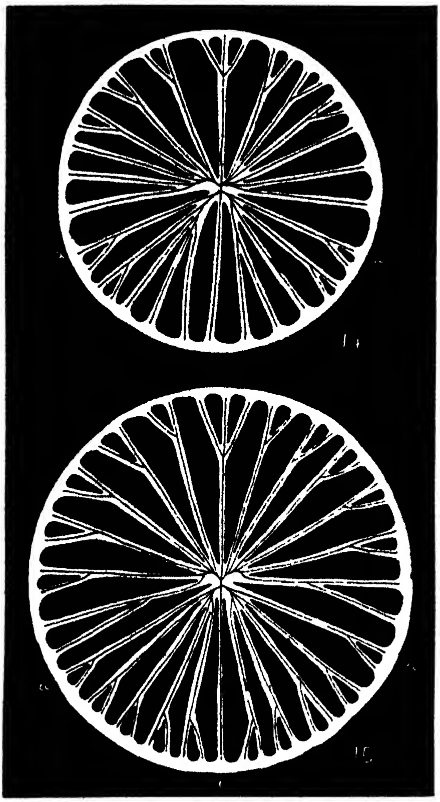


Figs. 12–13. *Stereolasma rectum*. (Enlarged.)

[1] See also J. E. Duerden, Biological Bulletin, Vol. IX, No. 1, pp. 35–36, June, 1905.

making the total number of secondary septa present in the adult corallite. Two more pairs of tertiary septa are added in the counter quadrants and three more in the cardinal quadrants.

Figure 16 is a section from near the base of the calyx. All the primary and secondary septa project freely into the cup. The cardinal septum is hardly as large as the others. The alar septa and all the secondary septa are about equally developed and each has a tertiary septum abutting against it. The counter septum is developed to a more marked extent and is longer than the others and has a tertiary septum on either side. All of these sections were sketched from the end of the corallite as it was ground away and are therefore more or less diagrammatic.



Figs. 14–15. *Stereolasma rectum.* (Enlarged.)

The statement stands unquestioned that a type occurring late in geological time, at least a considerable time subsequent to the earliest occurrence of a type at all similar, is likely to be far from primitive in at least some respects.[1]

That the counter quadrants of a rugose coral are accelerated in development over the cardinal quadrants is shown by the above discussion of *Stereolasma rectum*. One tertiary septum has appeared in each counter quadrant before the appearance of even one secondary septum in the cardinal quadrants. Three secondary septa appear in each counter quadrant before the appearance of the first secondary septum in the cardinal quadrants. In all seven secondary septa appear in each of the counter quadrants, while only four arise in the cardinal quadrants.

In *Stereolasma rectum*, moreover, the tertiary septa do not arise simul-

[1] See C. E. Gordon, American Journal of Science, vol. XXI, pp. 109–127, Feb., 1906.

taneously but come in in the same order as the secondary septa. The first one in each counter quadrant appears long in advance of any of the others, and when the others do appear, they follow the same sequence as the secondary septa. They develop more rapidly in the counter quadrants than in the cardinal, four having appeared in the former when there are only two in the latter.

This species agrees with *Enterolasma strictum* of the lower Devonic beds in that the tertiary septa are united with the secondary septa at their inner margins and do not project as free ridges as is the case with the tertiary septa in geologically earlier species.

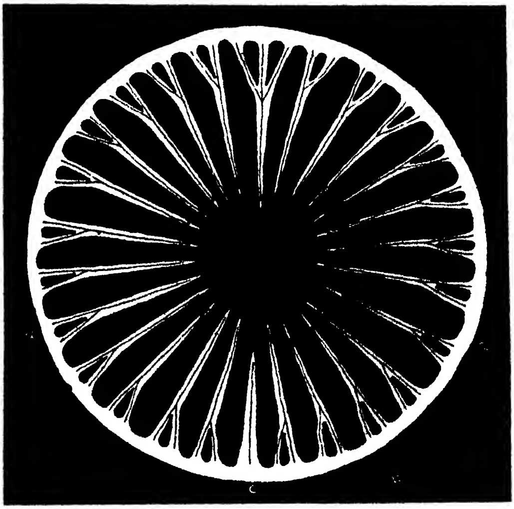


Fig. 16. *Stereolasma rectum.* (Enlarged.)

The additional figures are enlarged from the actual sections sawed from individual corallites. Figure 17 (a–e), from a comparatively small individual, shows five sections. In figure 17a there are only two pairs of secondary septa in the counter quadrants in addition to the four primary septa. The other four sections show the addition of the remaining secondary septa and of the first pair of tertiary septa adjacent to the counter septum, as well as the reduction in prominence of the cardinal septum and the development of the solid pseudocolumella. Figure 18 (a–g) shows similar stages in development and also the presence of tabulæ and dissepiments (shown by white in the interseptal spaces). Figure 19 (a–c), from near the base of the calyx of another individual, shows to better advantage the presence of tabulæ and dissepiments. These sections show particularly well the reduction of the cardinal septum and development of the cardinal fossula.

Heterophrentis prolifica *Billings.*

1859 *Zaphrentis prolifica* Billings, Canadian Journal, (new series), vol. IV, p. 121, figs. 22, 23.

1874 *Zaphrentis prolifica* Nicholson, Rept. on Pal. of Prov. of Ontario, pl. 3, figs. 2, 2a.

1874 *Heterophrentis prolifica* Billings, Canadian Naturalist, (new series), vol. VII, No. 4, Mar. 1874.

The authoritative description of this species is as fellows [1]:

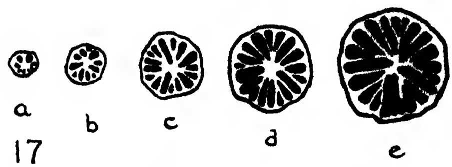


Fig. 17. *Stereolasma rectum.* (Enlarged.)

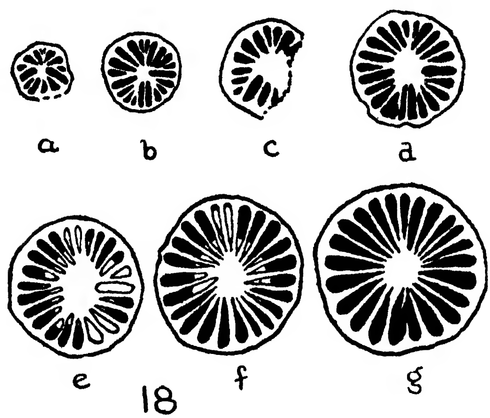


Fig. 18. *Stereolasma rectum.* (Enlarged.)

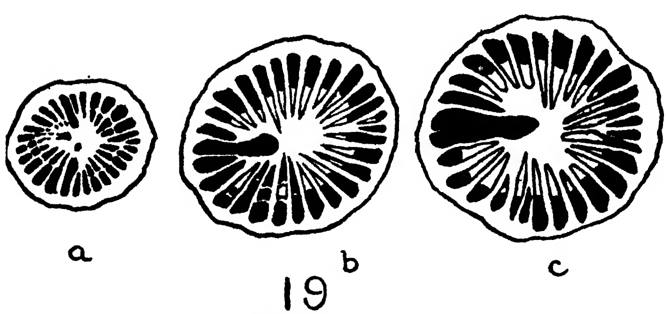


Fig. 19. *Stereolasma rectum.* (Enlarged.)

Corallum simple, turbinate, curved, expanding to a width of from 18 to 24 lines in a length of from two to four inches. Surface with a few undulations of growth.

[1] E. Billings, Can. Nat., (new series), Vol. VII, No. 4, p. 236, Mar., 1874.

Septal striæ, eight to ten near the base, and six to eight in the upper part, in a width of three lines. Septa from about one hundred to one hundred and twenty at the margin, where they are all rounded; most common number from one hundred to one hundred and ten. In general they alternate in size at the margin, the small ones becoming obsolete on approaching the bottom of the calyx, the large ones more elevated and sharp edged. The septal fossette is large and deep, of a pyriform shape, gradually enlarging from the outer wall inwards for one third or a little more of the diameter of the coral at the bottom of the calyx. Its inner extremity is usually broadly rounded, or sometimes straightish in the middle. It cuts off the inner edges of from eight to twelve of the principle septa, which may be seen descending into it to various depths. The surface layer of the bottom of the cup extends the whole width, bending down a little near the margin as in *Zaphrentis*, and uniting with the inner wall of the cup all around. It thus seems to represent one of the tabulæ of a Zaphrentis.

This species occurs abundantly in the Onondaga limestone of the middle Devonic and is a typical representative of the Heterophrentis group. In its adult condition this is a slightly curved conical shaped coral with a very distinctly marked fossula in the position of the cardinal septum, and with the other septa slightly twisted at the center. In this condition it is very distinct from the Streptelasma forms, but when its developmental stages are studied it is found to be more closely related.

In the accompanying figures are shown a few stages in the development of this form. Figure 20e is enlarged from a section sawed from the tip of a well preserved coral. It is almost identical with a slightly later stage in the development of a Streptelasma form. The four primary septa are most prominently developed and each extends to the center of the corallite. There are six secondary septa in each counter quadrant and five in each cardinal quadrant. Each secondary septum is attached by its inner margin to the next preceding septum. At this stage there is no indication of a fossula or any enlargement of the open spaces around the cardinal septum. If identified from this section alone, the species would be classed under *Stereolasma*. In figure 20f a later stage of the development of the same individual is shown. Additional secondary septa have developed in the four quadrants. The cardinal septum is becoming shortened, and the position of the fossula is beginning to be indicated although not yet distinctly marked. In figure 20a, a section from another individual, giving a stage intermediate in development between the two above described, the septa are all shown to be normally developed except the cardinal. The cardinal septum, although still reaching to the center of the corallite, is much thinner and less prominent than the other septa. Evidently it is being retarded in its development. Figure 20b, a later stage in the same individual, shows the cardinal septum no longer continuous to the center, and the fossula or open space occupying its

position is distinctly marked. Figure 20c, a still later stage, shows the cardinal septum very short and the fossula distinctly marked and bulging in appearance, while the secondary septa on either side are crowded away from the median line. The appearance of the tertiary septa is distinctly marked

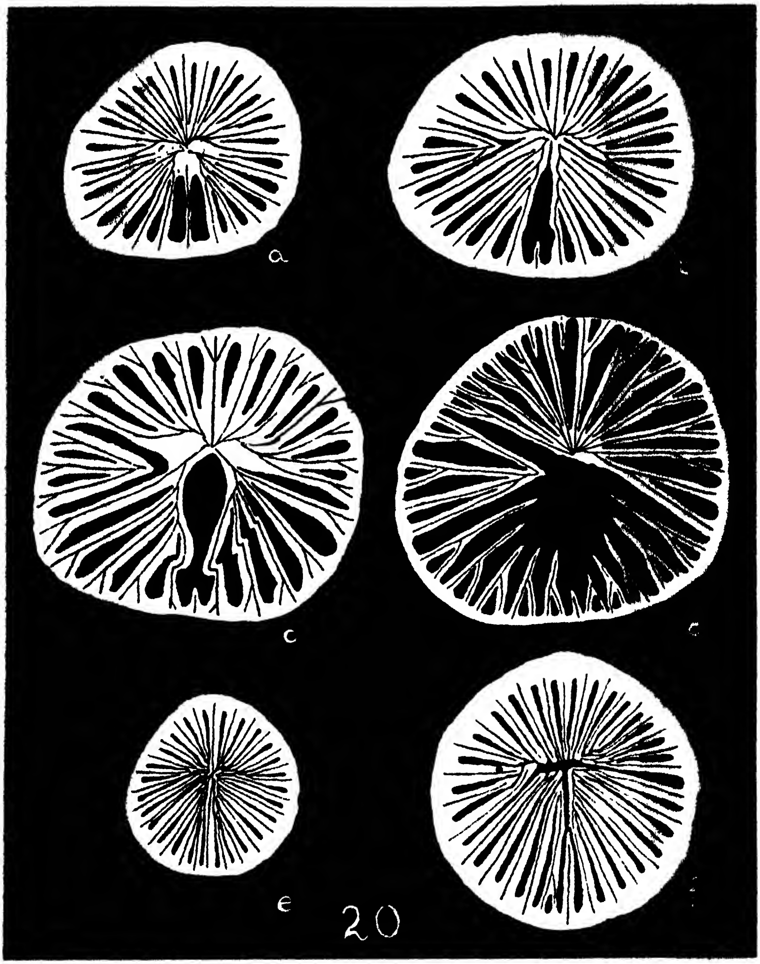


Fig. 20. *Heterophrentis prolifica.* × 4.

in this section, although calcification has continued until they are united throughout their length with the secondary septa. Their presence and position is indicated in the figure by the dark central line of calcification. In figure 20d, cut from the base of the cup, the adult condition is shown.

The cardinal septum, although very short, is still present. The alar septa and the secondary septa in the cardinal quadrants are less strongly developed than the septa in the counter quadrants. Tertiary septa are developed adjacent to all septa except the cardinal and the last two pairs of secondary septa in the counter quadrants. These latter are not fully developed as yet, and a later stage would show tertiary septa adjacent to them also. It will be noted that the two tertiary septa adjacent to the counter septum are no longer attached to this septum at their inner borders but project freely into the interseptal space.

Attention is further called to the fact that in the adult of this species there are eight secondary septa in each counter quadrant while there are only four in each cardinal quadrant, a condition similar to that found in the Stereolasma forms. The earlier stages of this form might easily be taken for those of a member of the Streptelasma group, and the whole individual development may be taken as that of a Streptelasma form with one new stage added as a final adult condition, namely: the fossula stage. Compare the open spaces or incipient fossula of *Stereolasma rectum*, which is a parallel development though less accentuated.

Heterophrentis multilamellosa *Nicholson.*

1875 *Zaphrentis multilamellosa* Nicholson, Paleontology of Ohio, vol. II, p. 236.

Heterophrentis wortheni *Nicholson.*

1875 *Zaphrentis wortheni* Nicholson. Paleontology of Ohio, vol. II, p. 235.

Heterophrentis edwardsi *Nicholson.*

1875 *Zaphrentis edwardsi* Nicholson, Paleontology of Ohio, vol. II, p. 235.

Heliophyllum halli *Edwards & Haime.*

1850 *Heliophyllum halli* Edwards & Haime, British Fossil Corals, p. 235, pl. LI, fig. 3.

Heliophyllum halli is a coral found in abundance in the middle Devonic shales of Eastern North America. Edwards and Haime describe it thus:

Corallum simple, turbinate, or cylindrico-conical, usually elongated, and slightly curved at its base, provided with an epitheca and presenting slight circular swellings. Calice circular, rather deep, with a small septal fossula. Septa (80 or even more) very thin, closely set, rather broad at their upper end, where they are arched and denticulate, alternately larger and smaller, slightly twisted near the center

of the visceral chamber. A vertical section shows that the lateral processes of the septa are arched and ascendant; those situated toward the upper end of the corallum terminate at the edge of the septa; those situated lower down unite near the center of the visceral chamber, so as to constitute irregular tabulæ. The interseptal loculi are filled up with these lamellate processes, which are situated at about half a line apart, and united by closely set simple dissepiments that form right angles with them. Diameter of calice from 1 to 2 inches.

While this description is exceptionally complete in so far as adult individuals are concerned, it, nevertheless, is of no value for the study of a genetic series. For such studies one must consider either a series of young individuals or the younger stages of adult individuals. The lateral processes or carinæ of the septa are a very characteristic feature of the adults of this genus, but even a limited study of the earlier stages shows that at first these individuals are without carinæ, and if specimens of this age were collected they could not be distinguished from the Streptelasma forms occurring in the same horizon. The accompanying six figures drawn from transparent sections cut from typical individuals of this species illustrate six of the characteristic stages of the development.

Figure 21a, sawed from the tip of one individual, shows the Streptelasma stage. In addition to the four primary septa there are present four pairs of secondary septa in the counter quadrants, two pairs of secondary septa in the cardinal quadrants and a pair of tertiary septa adjacent to the counter septum. No carinæ are present, and the arrangement of the septa is in every way identical with that found in a corresponding stage of a *Streptelasma*. Figure 21b is a rather poor slide cut from a slightly later stage of another individual. The individual septa cannot be identified but the presence of tertiary septa in practically all of the spaces between the septa of the primary and secondary order is worth noting.

Figure 21c, from a corresponding or possibly from an earlier stage of a third individual, shows the primary and secondary septa so that they can be easily recognized, while the tertiary septa are much longer than in the preceding figure. No carinæ are yet present, but in the section numerous fine lines cross between adjacent septa at intervals, and these may represent the origin of the carinæ or the points at which they are about to develop. In figure 21d, the Streptelasma arrangement of the septa still persists. In addition to the four primary septa there are seven pairs of secondary septa in the counter quadrants and three pairs in the cardinal quadrants with tertiary septa in all the interseptal spaces. One ring or circle of carinæ has appeared near the margin of the section. Figure 21e is a somewhat imperfect section from a still later stage. The individual septa cannot here be positively identified, but in that portion of the section which has not been

broken at the edge, three or four carinæ are clearly indicated on each of the septa.

Figure 21f is cut from near the base of the cup in an adult corallite. It shows clearly the primary and secondary septa alternating with the tertiary septa, which in this stage are nearly as long as the former. The septa of all three series have a considerable number of carinæ, and it is clearly seen that the carinæ near the center are stronger and heavier than those near the margin of the section. This is due to the fact that the carinæ near the

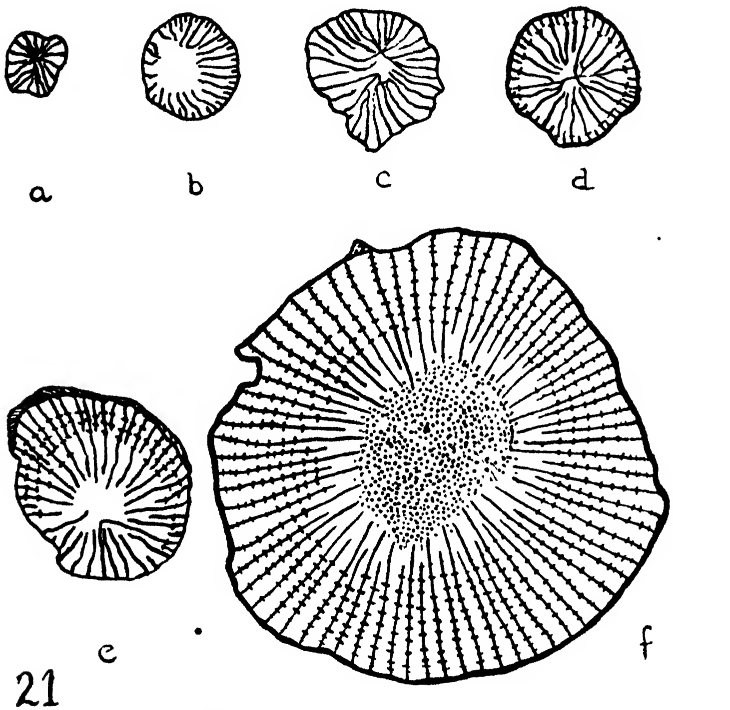


Fig. 21. *Heliophyllum halli.*

center are the first to arise, while new ones are added between the margin and those already present.

From the foregoing developmental study of the morphology of even such a distinct and specialized species as *Heliophyllum halli*, it is seen that in its younger stages it is only a *Streptelasma* and that the specialized characters are only later additions as the individuals approach their adult condition. *Heliophyllum halli* apparently gives rise to the compound form *Heliophyllum confluens* of the Hamilton, and then the line dies out. *Heliophyllum tenui-*

septatum and *Heliophyllum corniculum*, so called, do not appear to belong to this genetic series. The former species has been carefully studied, but in its early stages it seems to have no septa. The genetic relationship of this from is uncertain. The latter species, *H. corniculum*, apparently is not a *Heliophyllum*, but, as suggested by Grabau, belongs to an entirely different genetic series, namely *Heliophrentis* derived from the so called [*Zaphrentis*] *racinensis* of the Siluric.

Microcyclus discus *Meek & Worthen.*

This is a small flat circular coral form the Devonic beds. Duerden has found that in the earliest stages observable by grinding off the tip, six septa were present.[1] Others are added in the regular manner. In the adult condition the septa are more or less radially arranged and the septal fossula is well marked. This form seems to represent the beginning of that specialized line of development which ends with the retrogressive genus *Hadrophyllum.*

Hadrophyllum orbignyi *Edwards & Haime.*

Hadrophyllum is a genus of small size and depressed shape, having no hollow cup or calyx, but with the septa projecting above the exterior wall. Edwards and Haime, in their volume on British fossil corals, describe the genus thus: "Corallum short. Calice superficial. One very large septal fossula, and three small ones representing a cross. The radiate arrangement of the septa somewhat irregular." In Zittel's Text Book of Paleotology this description is slightly modified and reads thus: "Cushion-shaped, with epitheca. Calice with three septal fossulæ, that of the cardinal septum being the largest." The latter description seems to be correct in regard to the number of fossulæ or depressions adjacent to the primary septa, although only one of these depressions can correctly be called a fossula, the other two being pseudofossulæ. In all the specimens examined, there is a fossula present surrounding the cardinal septum, and two lateral depressions between the alar septa and the septa of the counter quadrants.

The genus *Hadrophyllum* is apparently highly specialized and probably represents the terminal member of a non-progressive or perhaps retrogressive series, in which the primitive pinnate arrangement of the septa, as found in *Streptelasma profundum*, has been retained and accentuated in the adult stage.

The type under consideration is the type of this species, and when the

[1] Annals and Magazine of Natural History. Sept., 1906.

stages of development of this species are studied, it is seen that the form arises from a Streptelasma-like stem. Duerden has studied the early stages of other species of this genus and found specimens in which there were only six septa in the youngest stage observed.[1] In figure 22a is shown a stage from the polished tip of a specimen in which eight septa are present. Two pairs of secondary septa have already arisen in the counter quadrants. Figure 22b, from the fractured tip of another individual, shows a later stage in which there are three pairs of secondary septa in the cardinal quad-

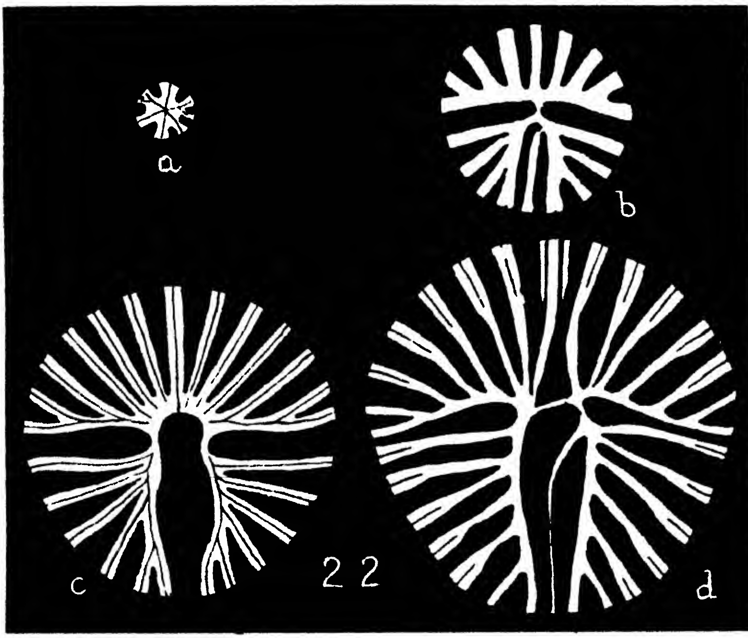


Fig. 22. *Hadrophyllum orbignyi.* × 4.

rants and four in the counter quadrants. The pinnate arrangement of the septa is already distinctly accentuated and the three fossulæ clearly defined. Figure 22c is a view from above the calyx of a small individual. Two more pairs of secondary septa have been added in each set of quadrants. The cardinal septum does not show in this specimen, but as the cardinal fossula was somewhat poorly defined, probably its absence was due to imperfect fossilization. Figure 22d is a similar view from a still larger individual. Another pair of secondary septa has been added in the counter and in the

[1] Science, Aug. 24, 1906. Annals and Magazine of Natural History. Sept., 1906.

cardinal quadrants. Tertiary septa are also present, adjacent to all the septa except the cardinal and the last two pairs of secondary septa in the counter and cardinal quadrants. Even in this form, in which the primitive arrangement of the septa is retained and accentuated, the counter quadrants develop slightly in advance of the cardinal quadrants. And furthermore, although this is a highly specialized form, it is clearly seen that it is derived from a Streptelasma-like ancestor, and the genus *Microcylus* probably connects this with the Streptelasma line.

IV. Carbonic Corals.

In the Devonic deposits we find sufficient evidence to prove that the rugose corals have passed the acme of their development and are on the decline. During the middle and latter part of the period typical progressive species become less abundant and their place is taken by highly specialized terminal forms, such as the *Heliophyllums* with the carinate character, the *Hadrophyllum* with the extremely short almost disc-like calyx and peculiar grouping of the septa in the four quadrants retained and intensified in the adult stage. At the end of the Devonic and beginning of the Carbonic the rugose corals have become a very meagerly represented and unimportant group of fossils. Only a very few genera and species yet remain, and, occurring as the last and terminal forms of such a long continued series, they might be expected to be specialized forms.

One of the species in the Carbonic limestones and one similar and closely related to the series under consideration in the present paper is *Lophophyllum proliferum*.

Lophophyllum proliferum *Edwards & Haime.*

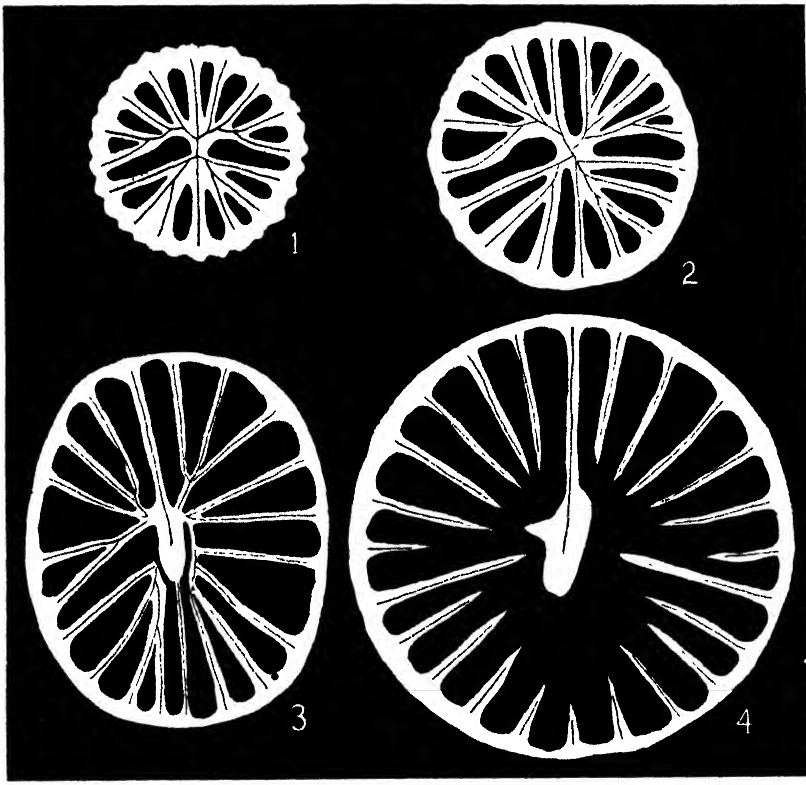
In their volume on British fossil corals, Edwards and Haime describe the genus Lophophyllum thus:

> Corallum resembling Zaphrentis, excepting by the great development of three primary septa, one of which is placed facing the septal fossula; this fossula extending much toward the center of the visceral chamber, and ceasing there to be distinct from the bottom of the calyx.

There is considerable material of this species in the collections of Columbia University, and sections were made and the individual development studied in the same manner as described in the preceding chapters. In sectioning the earlier stages, however, the writer did not meet with as good

success as was anticipated, and in the following discussion of this species his own sections are supplemented by a very good and complete series of sections copied from a paper by Duerden.[1] While the drawings are copied from Duerden, the writer alone is responsible for the interpretation of these drawings and in his interpretation differs widely from Duerden, but agrees with Gordon.[2]

In figures 1 to 4 are given four stages in the life of one individual. Figure



Figs. 1–4. *Lophophyllum proliferum.* × 8.

1 shows a comparatively early stage when the individual might easily be mistaken for almost any one of the Streptelasma species previously described. The septa are arranged in the same way and are at a stage comparable with

[1] Johns Hopkins University Circular, Jan., 1902. Annals & Magazine of Natural History May, 1902.

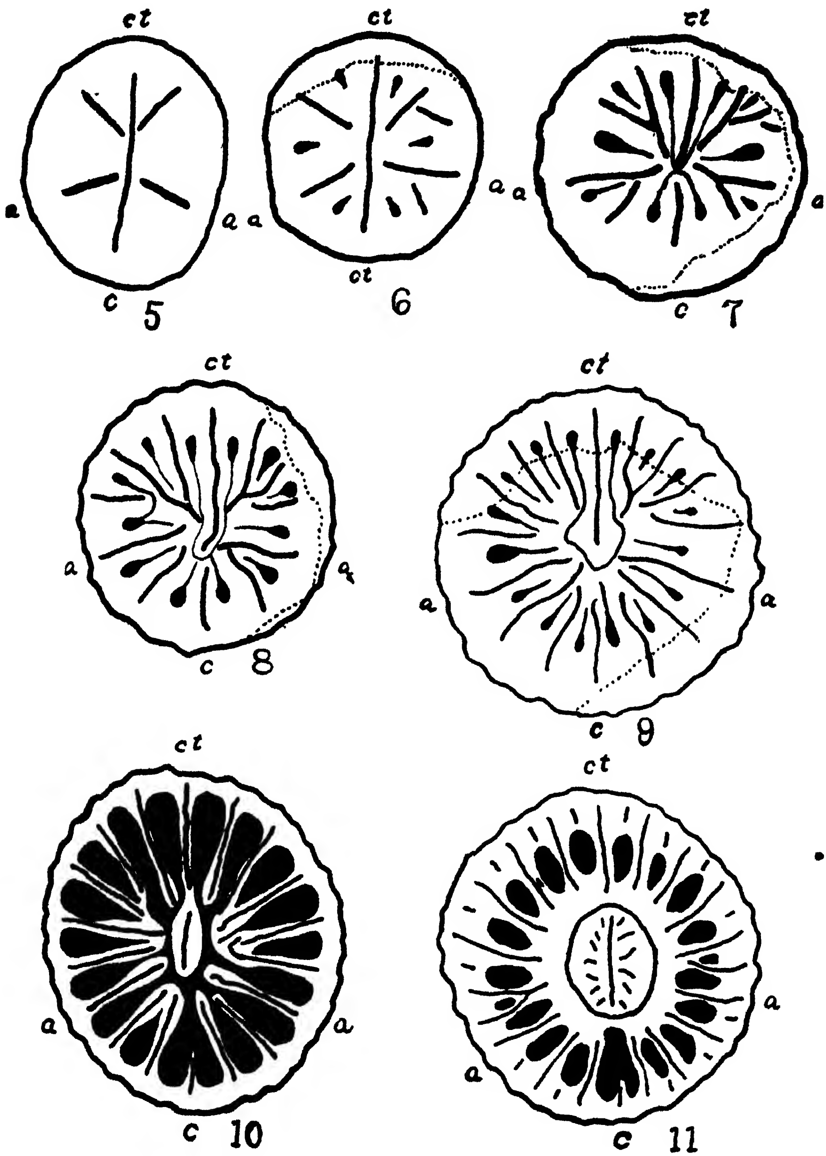
[2] Studies on Early Stages in Paleozoic Corals. Am. Jour. Sci. Feb. 1906.

the adult of *Streptelasma profundum*, with figures 10 to 12 of *Strereolasma rectum*, etc. The counter quadrants are accelerated over the cardinal quadrants as was the case with all the species previously discussed, four pairs of secondary septa having already appeared in the counter quadrants while only two pairs have appeared in the cardinal quadrants. In figure 2, the arrangement and development of the septa is still very similar to that found in the Streptelasma forms. Another secondary septum has appeared in one counter quadrant and another pair in the cardinal quadrants. No special indication of this particular species has yet appeared. It will be noted, however, that the septa do unite at the center to form a sort of pseudo-columella, but this character is not as yet any more marked than in *Stereolasma rectum*. In the section shown in figure 3, the form is distinctly marked as a *Lophophyllum* by the columella-like thickening at the inner end of the counter septum. An additional pair of secondary septa have appeared in both counter and cardinal quadrants, and the cardinal septum is becoming reduced in size. In figure 4, a section cut from the base of the open cup, we have a condition very similar to the adult condition found in *Heterophrentis prolifica*, except for the columella-like thickening at the end of the counter septum. The cardinal septum is very short. The other three primary septa are more prominently developed than any of the secondary septa.

Figures 5 to 11 represent the series of developmental stages of this same species, copied from Duerden. Figure 5 is from the tip of a coral individual and shows the earliest stage which was obtained. The four primary septa are present, and one pair of secondary septa have already appeared in the counter quadrants. Figure 6 is a section from a second individual at a higher level showing a later stage. In this another secondary septum has appeared in one counter quadrant, and one has appeared in the cardinal quadrant of the same side. Figure 7 is a section from a third individual at a still higher level. Two secondary septa have appeared in one counter quadrant, three in the other and one in each cardinal quadrant. Figures 8, 9 and 10 are sections from the same individual as figure 7, showing the later stages and the rate and manner of the addition of the secondary septa. Figure 10 illustrates a stage intermediate between that shown in figure 3 and that in figure 4. Figure 11 is from the upper region of a fourth individual and illustrates the final adult condition.

We thus see that the genus *Lophophyllum* in its individual development first passes through stages corresponding to the life history of the Streptelasma-Stereolasma line, then through a stage equivalent to the Heterophrentis stage characterized by a waning cardinal septum and very prominent fossula, and in its adult condition adds a new and specialized character, the columella-like thickening at the inner end of the counter septum. This genus

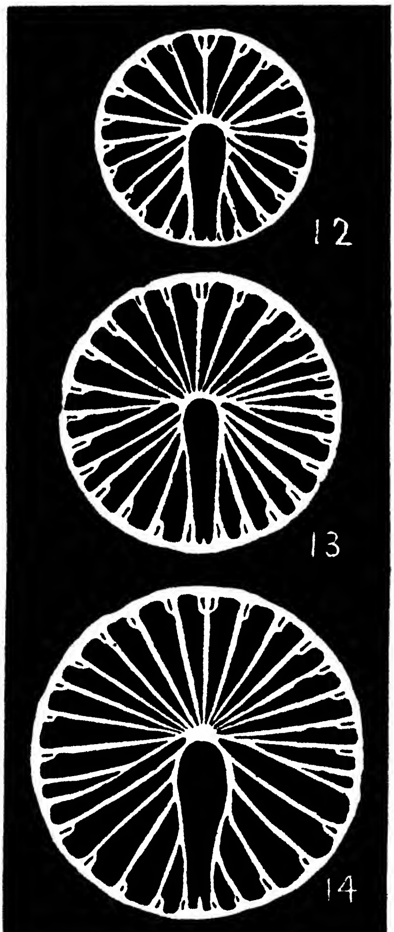
probably gives rise to *Cyathaxonia*, with a still more prominent pseudocolumella.



Figs. 5–11. *Lophophyllum proliferum.* (After Duerden.)

Hapsiphyllum calcareforme *Hall.*

1882 *Zaphrentis calcareformis* Hall, 12th Report of the State Geol. of Indiana, p. 293, pl. 21, figs. 10, 11.
1884 *Zaphrentis calcareformis* Hall, 35th Report New York State Museum, p. 437.
1900 *Hapsiphyllum calcareforme* Simpson, Bull. 39 New York State Museum, p. 203.



Figs. 12–14. *Hapsiphyllum calcareforme.* × 4.

Hapsiphyllum is a genus proposed by Simpson (*loc. cit.*) for certain rugose corals, the majority of which occur in the Lower Carbonic or Mississippic deposits. The genus is described thus:

Corallum small, simple, conical or horn-shaped; calyx circular, comparatively deep, with thin margins; biareal. The outer area is bounded by the external epitheca; the inner area by a sub-vertical wall of horse-shoe shape, open on the side of the septal fovea. Two of the larger septa connect with this wall in such a manner as to be apparently a continuation of it, and form a very distinct pyriform septal fovea; septa alternating in size, the smaller ones continuing for a short distance into the cavity of the corallum, there coalescing with the larger ones, which continue to the inner wall, with which they coalesce, and in which they terminate. Tabulæ and dissepiments are present.

Hall (*loc. cit.*) describes the species thus:

Corallum simple, narrowly turbinate, regularly curved; diameter of calices of individuals of the same height varying from 10 to 15 mm.; exterior with frequent undulations and low rounded annulations; height 25 mm.; fossette narrow, very deep, commencing at the center and continuing to the posterior margin; the lamellæ extending to its margin coalescing and forming vertical walls; number of lamellæ 50, alternating in size; at a distance of 2 mm. from the margin the smaller lamellæ coalesce with the others. This species is easily distinguished by the deep, narrow fossette situated on the anterior side and the regular coalescing of the lamellæ at a short distance from its margin.

Although reported by Hall from the Onondaga (Corniferous) at the Falls of the Ohio, the individuals of this species studied were from the St. Louis Group at Button Mould Knob, Ky. In its younger stages, this species passes through a development similar to the Streptelasma line, then through the Heterophrentis stage and becomes specialized by changing the fossula of the Heterophrentis stage into an inner wall. The inner wall condition is much more clearly shown in the sectional views of *H. varsoviense* given later.

The accompanying figures show the typical stages in the life of this form after it has attained the Hapsiphyllum characters. Figure 12 is of a small and rather young individual showing a condition hardly distinguishable from an *Enterolasma* or *Stereolasma*. Figures 13 and 14 show later stages with the Hapsiphyllum characters more pronounced, but in none of these are these characters as prominent as in the species to be described later.

Attention is here called to the similarity between the development of the inner wall in this species and the development of the inner wall of *Craspedophyllum subcæspitosum*, a compound branching form from the Devonic described by G. E. Anderson.[1]

Hapsiphyllum spinulosum *Edwards & Haime.*

1851 *Zaphrentis spinulosa* EDWARDS & HAIME, Pol. Foss. des Terr. Pal., p. 334.
1890 *Zaphrentis spinulosa* WORTHEN, Geol. Sur. Ill. vol. VIII, p. 73, pl. X, figs. 6, 6a.

In the latter reference, this species is described thus:

> Coral turbinate, moderately elongated, a little curved and slightly distorted, with a few irregular external ridges; epitheca thin and on the lower portions ornamented with little sub-spiniform points; cup circular, moderately profound; fossette moderately developed, situated near the wall but in a variable position from conforming to the curvature; lamellæ about 30, very feebly curved near the septal fossette, with an equal number of rudimentary lamellæ.

Figures 15 and 16 are two typical sectional views of this species and show a slight advance over the preceding species. The inner wall is a trifle more prominently developed, and the tertiary septa are longer, more prominent and wider separated from the primary and secondary septa.

Hapsiphyllum varsoviense *Worthen.*

1890 *Zaphrentis varsoviensis* WORTHEN, Geol. Sur. Ill., vol. VIII, p. 78, pl. 10, figs. 9, 9a.

[1] "Studies in the Development of Certain Palæozoic Corals," Journal of Geology, vol. XV, No. 1, 1907.

Worthen (*loc. cit.*) describes the species thus:

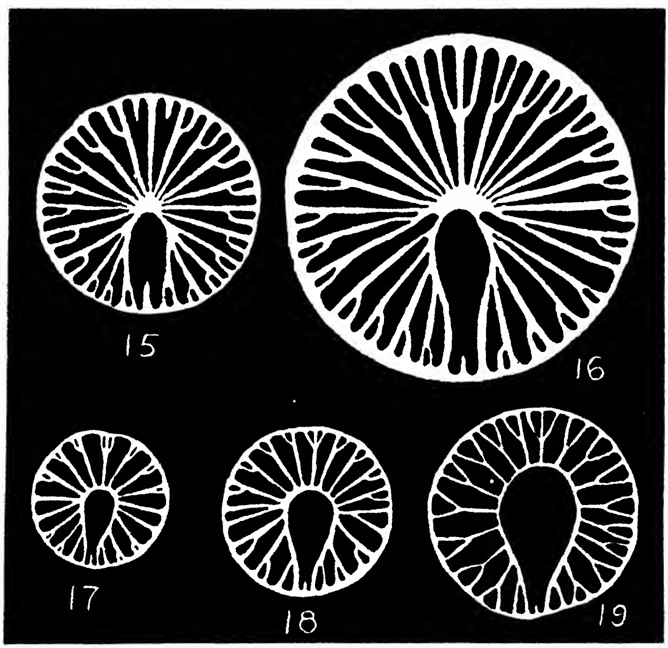
Corallum small, turbinate, pointed below, and slightly curved; epitheca thin, external striæ distinct; height of corallum one inch; breadth of cup 7/8 inch; depth of same 1/4 inch.

Septal fossette nearly central, and extended on the side of the greatest curvature; primary lamellæ comparatively strong, and numbering about 26, all reaching the thickened border of this septal fossette.

Quite common in the Keokuk limestone at Warsaw, Hamilton, Nauvoo and Keokuk.

The specimens studied and figured in this paper were from Lanesville, Ind.

This species, in so far as the characteristic inner wall is concerned, shows



Figs. 15–16. *Hapsiphyllum spinulosum.* × 4.
Figs. 17–19. *Hapsiphyllum varsoviense.* × 4.

an advance over *Hapsiphyllum calcareforme* and *H. spinulosum* The three sectional views figured are from three different stages of three individuals and show the manner of individual development and change from the Hapsiphyllum calcareforme condition, which is almost identical with figure

17, to the typical Hapsiphyllum varsoviense adult condition which is shown in figure 19. This shows the completed inner wall, complete except for the gap at the cardinal septum. A slight change has also taken place in the condition of the tertiary septa. Instead of being short and close to the side of the primary and secondary septa they are now nearly or quite half as long as the secondary septa and are widely separated from them except at their inner margins. This condition is very clearly shown in figure 19.

V. Observations on Development.

From the foregoing studies of the Streptelasma group of the rugose corals it is seen that this group is first known from the true Streptelasma forms found in the middle Ordovicic. By gradual changes as we pass into the higher and geologically later horizons these very early forms give way to more complex and more specialized forms. The changes and specialization are not confined and directed along any one particular course, but form rather a gradually branching series, the various branches being more or less parallel to one another but at the same time quite distinct. Each one of these particular branches or lines of development reaches a certain climax and then rapidly declines and disappears. At the close of the Devonic period only a few are left and at the end of the Carbonic all are gone, in North America at least.

The earliest representatives of the rugose corals yet recognized, namely the Streptelasmas of the middle Ordovicic, are by no means primitive although they are without a doubt ancestral to a large majority of the succeeding genera and species. *Streptelasma profundum* is a well developed coral, although it is the earliest one recorded. The questions which now confronts us are: What was the ancestor of *Streptelasma profundum*? and What was it like? This ancestral form has not yet been found, and until it is found we shall have to be content with deducing from all the known facts the probable characters of this ancestral form. In such deductions two different lines of investigation must be followed out; first a study of the early embryonic development of similar forms living at the present time; second a study of the early stages of development of all the available later forms. Since there are no living representatives of the rugose corals, and since the mode of development of the hexacorals is so widely different from that of the rugose corals, we have to pass the first named line of investigation after drawing only a few of the most general inferences.

Duerden has carried on extensive studies on the embryology of certain recent corals but in each case finds that the embryo is well started before the

early skeleton is deposited. H. M. Bernard has made a special study of the prototheca of the Madreporaria,[1] and describes the results of his studies as follows:

> The most important stage to establish in an evolutionary history is the first, or that which we may consider as the first, inasmuch as from it all the modifications we wish to compare can be deduced. The first stage in the evolution of the coral skeleton was first dimly recognized by me in the minute saucer-shaped cups of young Madreporidan colonies — so young as to consist only of a parent calicle and one or two daughters. In none of the Madreporids have I yet found the earliest stage in which the cup containing the parent alone was cup shaped. Such a stage, however, may be legitimately assumed.

But he prefaced the above remarks with the following statement, which shows that he clearly recognized that the early stages of modern corals were of trifling value in giving us a clear idea of the primitive characters of Paleozoic forms.

> Furthermore, let me add in passing that I do not believe that the study of the individual development of a few living forms can by itself establish anything certain about the past history of the group, for the simple reason that we cannot tell whether any special developmental feature is a repetition of some ancient condition or a recent adaptation. As I have already often maintained, lines of phylogenetic growth can only be satisfactorily established by the discovery of connected series of variations, morphologically and chronologically arranged. The skeleton alone can supply us with such series, and that of the corals probably with a more complete series of forms, extending *from the Paleozoic era to the present day, than will ever be obtained of any other group.* Whether, therefore, the skeleton be of great or of little importance in itself in the morphology of the corals, it alone supplies us with what we want — a continuous series of homologous structures.

Since the skeletons themselves must be depended upon to give us the primitive characters of the earliest forms, we must turn to them and see what they indicate as the primitive ancestral coral. For this ancestral form the name *Protostreptelasma* is proposed.

Protostreptelasma is, therefore, an ancestral genus not yet discovered from the upper Cambric and lower Ordovicic deposits. It has already been shown that *Streptelasma profundum* is the earliest rugose coral yet known in North America and that in the very youngest stages of this form no septa are present. This is a constant character found in the youngest stages of all the specimens studied and so must be a primitive character. Some of the very small specimens were found without any septa at any stage and were sometimes straight and sometimes curved. Therefore we can

[1] "On the Prototheca of the Madreporaria," Annals and Magazine of Natural History, Jan., 1904, p. 1.

say that *Protostreptelasma*, the ancestral genus, is a rugose coral having a hollow conical or horn-shaped calyx, straight or slightly curved, without septa or having only a few rudimentary ridges near the upper margin indicative of septa.

Several hollow, conical, tube-like fossils have been found in the upper Cambric deposits which have been referred to as gastropods or pteropods because of their general resemblance to certain modern representatives of these groups. It is possible that certain of these may really be the fossil remains of the primitive ancestral coral which has been assumed and named *Protostreptelasma*.

Having assumed what may legitimately be considered the ancestral form, it is now possible to trace out the phylogeny of the Streptelasma group of rugose corals, basing the interpretation of the various steps in the development on the ontogenetic development of representative individuals from the various genera and species. The assumed ancestral genus *Protostreptelasma* during the early Ordovicic gave rise to the earliest known representative of this group, *Streptelasma profundum*. In this species the primitive non-septate condition is crowded into the very youngest stage of the ontogenetic development, while in the later stages the well-developed tetramerally arranged septa are the most prominent character. Four primary septa first appear, and these are followed by secondary septa added in pairs in the counter and cardinal quadrants. In the adult only a few of the septa reach to the center. The others extend down the interior of the cup and are attached each by its inner margin to the secondary septum next preceding it in the order of appearance. In this way nearly all the secondary septa are united in a pinnate manner and leave a well-defined open space along either side of the cardinal septum and a space on the dorsal side of each alar septum. The tertiary septa appear in the interseptal spaces in the same order as the secondary septa. They remain short and free throughout their whole extent and never appear to be attached to the adjacent secondary septa.

Passing now to *Streptelasma corniculum* and *S. rusticum*, the most abundant representatives of the Streptelasma group in the upper Ordovicic limestones, we find an advance in development beyond the *S. profundum* condition along one particular line. As an adult form, *S. corniculum* is much larger than the species just considered; it has more numerous septa; they are more nearly radially placed and the counter quadrants are accelerated over the cardinal quadrants. At the first glance it seems to have lost the four-fold structure so characteristic of the earlier species. But when the ontogeny or individual development is studied, it is seen that each individual first passes through a stage corresponding to the adult condition of *S. pro-*

fundum and then acquires the characters which are distinctive for this species. It is further to be noted that the fully developed septa never unite at the center to form a pseudocolumella. Only the incompletely developed septa are attached by their inner margins to the next preceding septa.

Streptelasma rusticum passes through the same development as *S. corniculum* but is distinguished from it in the adult stage by its long cylindrical manner of growth; the latter is cone-shaped throughout its life while the former is cone-shaped during its early life but becomes cylindrical in its adult condition.

It is appropriate at this point of the discussion to make note of a paper by F. W. Sardeson published a few years ago, entitled "On *Streptelasma profundum* (Owen) and *S. corniculum*, Hall.[1]" In this paper, Sardeson advocates including under one species, *Streptelasma profundum*, twelve or more species of this genus and three or more species of the genus *Zaphrentis* described from the various Ordovicic limestones of the United States and Canada. He notes the great difference in size of the geologically early and later forms and the difference in rate of expansion or angle of the apex in the different species and also that certain forms such as *S. corniculum* are always conical or horn-shaped, while others like *S. rusticum* become cylindrical, yet he believes that these should all be considered simply as individual differences due to the length of the life of the particular individual. He contends that they should all be grouped as one species, because individuals indicating gradations from one condition to another can be found. In arguing from this that they should all be one species he ignores the fundamental conceptions of all animal evolution, namely: that if all the individuals of any genetic series were preserved, there would be no sharp line of distinction or demarcation between one species and another but that an unbroken series of intermediate forms would be found which would show all stages of the change from the one species to the other. To the mind of the writer the amount of change in passing from *Streptelasma profundum* to *S. corniculum* and from this to *S. rusticum* is sufficient to constitute a valid specific distinction. The numerous other species of *Streptelasma* from the Ordovicic have not been studied, but probably most of them are valid species also.

The Streptelasma profundum-corniculum-rusticum line of development in so far as the Streptelasma stem is concerned seems to close with the Ordovicic. Perhaps this line of development in the Devonic gives rise to the Cyathophyllum stem. The present investigation has not been carried far enough either to prove or to disprove this supposition.

During the Siluric period the Streptelasma line of development advances

[1] American Geologist, Vol. XX, Nov., 1897.

another step to the genus *Enterolasma* and seems to be represented by the single species *Enterolasma caliculum*, occurring in the limestones and shales from the Clinton to the Cobleskill. In its younger stages *Enterolasma caliculum* passes through the same development as *S. profundum* and *S. corniculum*. It does not appear to be a derivative of *S. corniculum*, however, but seems to have been derived from another line by parallel development, because this form never attains the large size or very numerous and thick septa of *S. corniculum*. Yet the septa do become more or less radially arranged, and the acceleration of the counter quadrants over the cardinal is carried even farther than in *S. corniculum*. It is even seen in this species that the acceleration of the counter quadrants over the cardinal quadrants progressively increases during the life of the individual and becomes strongly marked during the later stages.

While the fully developed septa of *S. corniculum* project freely to the center and do not unite to form a pseudocolumella, the septa of this species do unite at the center to form a somewhat incomplete or irregular pseudocolumella, which is the characteristic of the next step in advance along the line of morphological development. Throughout the Siluric, although individuals are very numerous, there is no increase or marked variation of the species. The ancestral stages of development are crowded far forward into the early part of the individual development, and the later stages are chiefly characterized by the peculiar, incompletely developed pseudocolumella.

It is probable that [*Zaphrentis*] *racinensis* from the Niagara beds of Wisconsin represents one of the first lateral branches from the main Streptelasma stem, but material of this species is not available for ontogenetic study.

In the lower Devonic beds, as represented by the limestones of the Lower Helderberg series, *Enterolasma* is still the dominant genus and is here represented by the species *E. strictum*. In this species, although the pseudocolumella is far from being solid, it is yet much more substantial than in the Siluric species. Another characteristic which marks a change between the Siluric forms and this is the manner of attachment of the inner margins of the tertiary septa to the adjacent secondary septa. In all the earlier forms, the tertiary septa are free throughout their length. In this and the majority of the later forms, they are attached by their inner margins to the adjacent primary or secondary septum immediately dorsal to them.

During about one half or even more than one half of the geological time through which the Streptelasma group of rugose corals is distributed, its range of variation is very limited, and its changes are along conservative lines. With the close of the lower Devonic, however, this limited variation and conservative development is suddenly ended, and the Streptelasma

stem gives rise to numerous widely diverging lines which rapidly develop and specialize along some particular line, some progressive and some retrogressive, and then terminate and disappear. The development of this group of corals can best be compared to the flight of a sky rocket. It starts from the ground with a sputtering, throwing out a few sparks, then shoots upward through the air with a straight or slightly wavering course and with perhaps an occasional flicker until a certain height is reached, when suddenly it bursts and throws out sparks in all directions, some up, some down and some horizontally.

At the end of the lower Devonic comes the bursting stage in the Streptelasma line. This single genetic series now seems to give rise to diversified groups which branch out in all directions, some lines advancing in a progressive way but in different directions, while others seem to retrogress and return to a condition somewhat similar to ancestral stages but distinctly marked as degenerate series.

During the lower Devonic or Lower Helderberg period, the Streptelasma line of development is represented by *Enterolasma strictum*. This is very similar to the representatives of the same genus from the Siluric but is characterized by a somewhat more solid and substantial pseudocolumella and by the union of the tertiary septa with the adjacent primary and secondary septa at their inner margin.

With the middle Devonic, the rapid divergence of the various lines of development begins. The line of development representing the apparently most direct continuation of the Streptelasma line is that represented by *Stereolasma rectum*, occurring most abundantly in the Hamilton shales. This species differs from *Enterolasma strictum* only in the fact that it has a complete and solid pseudocolumella reinforced by a deposit of stereoplasm between the septa and near the pseudocolumella.

Closely related to these Streptelasma forms and either derived directly from them or coming from [*Zaphrentis*] *racinensis* of the upper Siluric (which in turn is derived from the Streptelasma stem) are a group of Zaphrentids found abundantly in the Onondaga limestone. *Heterophrentis prolifica* is typical of this group. It represents a line in which the emphasis of development falls upon the cardinal fossula rather than upon the pseudocolumella as is the case with *Stereolasma rectum*. Other closely related and congenetic species are *H. multilamellosa*, *H. wortheni* and *H. edwardsi*, all from the Onondaga beds.

Arising from the Streptelasma stem at about the same time and closely paralleling in its early development *Stereolasma rectum*, the species *Heliophyllum halli* represents another divergent line of development. During its early development this species cannot be distinguished from *S. rectum*,

but in its adult condition it is characterized by a new and distinctive feature, namely: the presence of carinæ or lateral ridges on the sides of the septa. This line of development apparently becomes extinct after it gives rise to the compound form *Heliophyllum confluens*. Other species described as Heliophyllums, such as *H. tenuiseptatum*, apparently do not belong to this genetic series. An attempt was made to connect the latter species with this series, but it could not be done. In sections made from the very early stages of this species, no septa could be found. In the earliest stage in which septa were found they were all rather short and only extended a short distance from the wall into the calyx.

Another line of development in this same period, and one characterized by a reversion to ancestral features coupled with a very specialized manner of growth, is represented by the genera *Microcyclus* and *Hadrophyllum*. The particular species studied was *Hadrophyllum orbignyi*, which in its development illustrated very well the early Streptelasma mode of arrangement and development of the septa followed by a very specialized short cushion-shaped growth of the calyx as a whole and the primitive pinnate arrangement of the septa within the calyx.

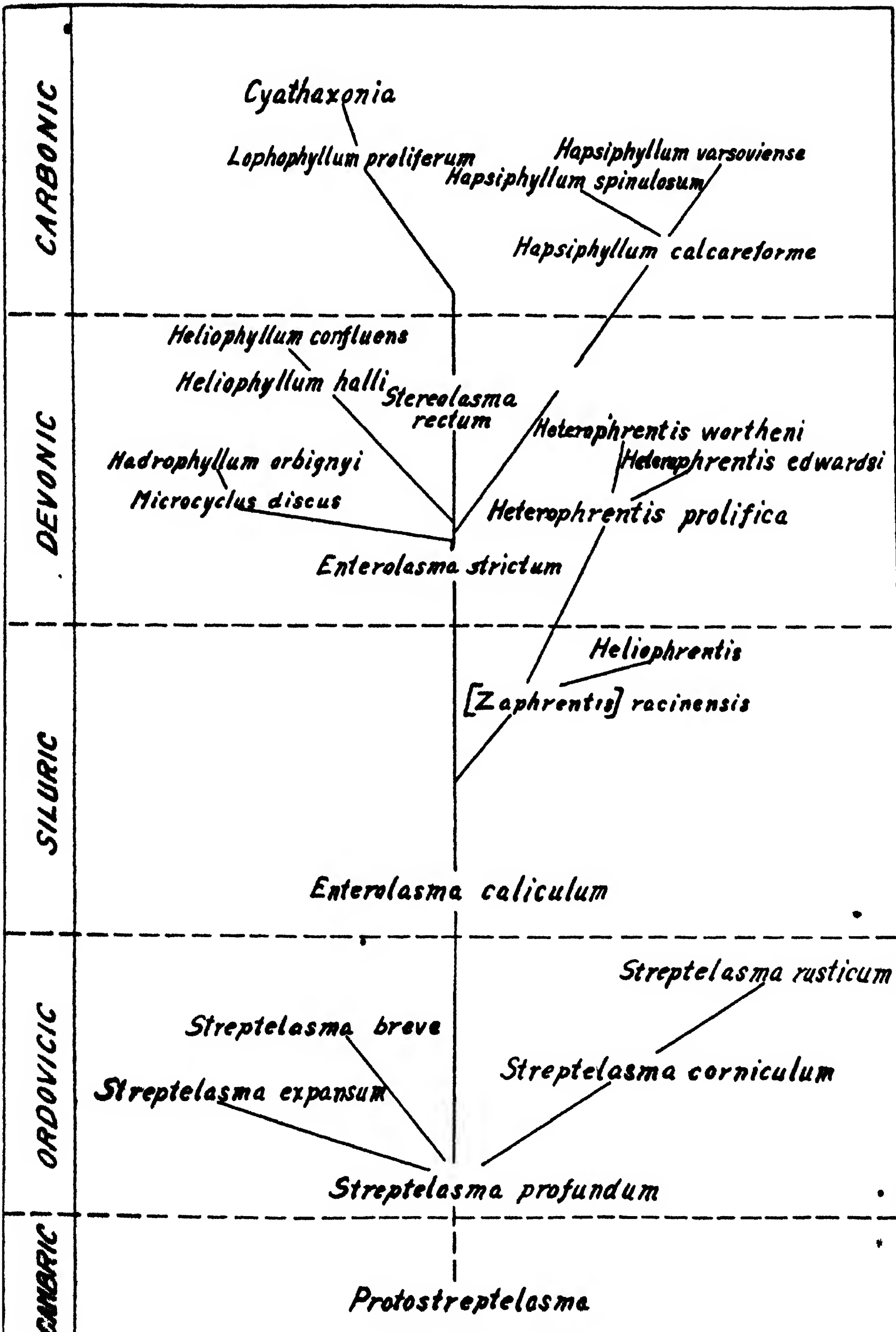
Possibly there may have been other lines of development which branched off from the same ancestral stem during the Devonic, but the ones described above are the only ones which have been considered in this study.

In the Devonic period the acme of development both of the rugose corals in general and of the Streptelasma group in particular is reached and passed. With the beginning of the Carbonic only a few terminal members of the various series are left and at the close of the Carbonic the whole group is extinct.

Among the Mississippic and Carbonic forms closely related to and apparently directly derived from the Devonic forms discussed above are the two genera *Lophophyllum* and *Hapsiphyllum*. The genus *Lophophyllum* is apparently directly derived from *Stereolasma*, and the prominent pseudo-columella of the latter is even more emphasized in the former and is carried up in the calyx of the individual corallites above the point where the fully developed septa unite, and, attached only to the inner edge of the counter septum, it projects up into the open cup. *Hapsiphyllum*, on the other hand, is apparently derived from the Heterophrentis line. The cardinal fossula, which in *Heterophrentis* is a prominent character, is in this species so accentuated that it forms a true inner wall. A study of the development of *H. calcareforme* illustrates the change from the Heterophrentis stage to the primitive true inner wall stage, and the development of *H. varsoviense* carries the change still further and gives the very prominent inner wall condition.

These Mississippic and Carbonic genera are two of the most persistent terminal members of the Streptelasma series, but with the Carbonic these forms, too, disappear. This Streptelasma series passes through the stages characteristic of all evolutionary series. First starting from very simple primitive forms it passes through a long slow period of development during which new characters are added little by little. At last the acme of development is reached. The stem branches off into divergent and highly specialized lines. As soon as this high specialization and divergent development begins, the group as a whole seems to lose vitality, and it rapidly declines and disappears. A few of the terminal members seem either to have more vitality or to be better adapted to the surrounding conditions than the others and they last a little longer, but even these at length are unable longer to resist and finally disappear.

The diagram on the following page shows the probable relationship of the various genera and species discussed in this paper.


CARBONIC
DEVONIC
SILURIC
ORDOVICIC
CAMBRIC
Cyathaxonia
Lophophyllum proliferum
Hapsiphyllum varsoviense
Hapsiphyllum spinulosum
Hapsiphyllum calcareforme
Heliophyllum confluens
Heliophyllum halli
Stereolasma rectum
Heterophrentis wortheni
Heterophrentis edwardsi
Hadrophyllum orbignyi
Microcyclus discus
Heterophrentis prolifica
Enterolasma strictum
Heliophrentis
[Zaphrentis] racinensis
Enterolasma caliculum
Streptelasma rusticum
Streptelasma breve
Streptelasma expansum
Streptelasma corniculum
Streptelasma profundum
Protostreptelasma

BIBLIOGRAPHY.

ANDERSON, G. E., Studies in the Development of Certain Paleozoic Corals, Journal of Geology, Vol. XV, 1907.

BILLINGS, E., Geology of Canada (Palæozoic Fossils.)

—— Canadian Journal, (new series), Vol. IV, 1859.

—— Canadian Naturalist, (new series), Vol. VII, 1874.

BERNARD, H. M., On the Prototheca of the Madreporaria, Annals and Magazine of Natural History, Jan., 1904.

BROWN, T. C., Developmental Stages in *Streptelasma rectum*, Hall, American Journal of Science, Vol. XXIII, Apr., 1907.

CARRUTHERS, R. G., The Primary Septal Plan of the Rugosa, Annals and Magazine of Natural History, Nov., 1906.

DUERDEN, J. E., The Morphology of the Madreporaria, Johns Hopkins University Circular, Jan., 1902.

—— The Morphology of the Madreporaria, Annals and Magazine of Natural History, May, 1902.

—— The Morphology of the Madreporaria, VI, The Fossula in Rugose Corals, Biological Bulletin, Vol. IX, No. 1, 1905.

—— The Morphology of the Madrepororia, The Primary Septa of the Rugosa, Annals and Magazine of Natural History, Sept., 1906.

EDWARDS and HAIME, See MILNE-EDWARDS et HAIME.

GIRTY, G. H., 14th. Annual Report of the New York State Geologist, 1894.

GORDON, C. E., Studies on Early Stages in Paleozoic Corals, American Journal of Science, Feb., 1906.

GRABAU, SHIMER and — See SHIMER.

GRABAU, A. W., North American Index Fossils, 1907.

HALL, JAMES, Geological Report of the 4th District of New York, 1843.

—— Palaeontology of New York, Vol. I, 1847, Vol. II, 1852; Vol. IV, 1887.

—— Illustrations of Devonian Fossils, 1876.

—— 32nd and 35th Reports of the New York State Museum.

—— 11th and 12th Reports of the State Geologist of Indiana.

—— Report of the New York State Geologist for 1882, 1883.

HYATT, ALPHEUS, Genesis of the Arietidæ, Smithsonian Contributions to Knowledge, 1889.

JAKOWLEW, N., Ueber die Morphologie und Morphogenie der Rugosa, Verhandlungen der Russisch-Kaiserlichen Mineralogischen Geselschaft, Bd. XLI, Lief. 2, 1904.

KUNTH, A., Beiträge zur Kenntniss fossiler Korallen, Zeitschrift der deutschen geologischen Gesellschaft, Bd. XXI, 1869 und Bd. XXII, 1870.

LUDWIG, R., Actinozoen und Bryozoen aus dem Carbonkalkstein im Government Perm, Palæontographica, vol. X, 1861–63.

—— Korallen aus Palæolithischen Formationen, Palæontographica, vol. XIV, 1865–1866.

MILNE-EDWARDS, H., et HAIME, J., Monographie des Polypiers fossiles des terrains paléozoiques, Arch. du Museum, Paris, Vol. V, 1851.

—— Monograph of the British Fossil Corals, Palæontographical Society, 1849–1864.

NICHOLSON, H. A., Paleontology of Ohio, Vol. II, 1875.
—— Report on the Palæontology of the Province of Ontario.
OWEN, D. D., Geological Explorations of Iowa, Wisconsin and Illinois, 1844.
POURTALES, L. F de, Deep Sea Corals, Illustrated Catalogue of the Museum of Comparative Zoölogy of Harvard College, Vol. IV, 1871.
ROMINGER, CARL, Paleontology of the Lower Peninsula of Michigan, Vol. III, 1876.
SARDESON, F. W., On *Streptelasma profundum* (Owen) *S. corniculum* Hall, American Geologist, Vol. XX, 1897.
SHIMER, H. W., and GRABAU, A. W., Hamilton Group of Thedford, Ontario, Bulletin of the Geological Society of America, Vol. VIII, 1902.
SIMPSON, G. B., Preliminary Descriptions of New Genera of Paleozoic Rugose Corals, Bulletin of the New York State Museum, Vol. VIII, No. 39, 1900.
SCHUCHERT, WINCHELL and — See WINCHELL.
WHITFIELD, R. P., Geology of Wisconsin, Vol. IV, 1882.
WORTHEN, AMOS H., Geological Survey of Illinois, Vol. VIII, 1890.
WINCHELL, A. and SCHUCHERT, CHARLES, Minnesota Geological and Natural History Survey, Final Report, Vol. III, Part I, 1891.


ESQUISSE GEOLOGIQUE
DE LA
BELGIQUE
TERRAINS PRIMAIRES
T. TRIASIQUE
BERNISSART
NAMUR
HUY
DINANT
PHILIPPEVILLE
GIVET
MARCHE
Durbuy
Stavelot
VERVIERS
Limbourg
BASTOGNE
St Hubert
NEUFCHATEAU
Kilomètres

PLATE IV.

Geological Sketch Map of Belgium.

Scale, 1 inch = 37.5 miles.

[ANNALS N. Y. ACAD. SCI., Vol. XIX, No. 4, Part I, pp. 99–119. 31 July, 1909.]

THE FOSSIL VERTEBRATES OF BELGIUM.[1]

BY LOUIS DOLLO.

Professor in the University of Brussels; Curator of the Department of Living and Fossil Vertebrates of the Royal Belgian Museum of Natural History. Corresponding Member New York Academy of Sciences.

PART I. MESOZOIC.

A. The most ancient Vertebrates of Belgium.

In the present state of our knowledge (1908) we think that

1. Fishes first appear in the Gedinnien (lower Devonian) of Ardennes (at Glaireuse in the commune of Villance, near Saint-Hubert, province of Luxembourg) in the form of an Ostracoderm, *Pteraspis dunensis* ROEMER, 1854. (L. DOLLO, Comptes rend. Acad. Sci., Paris, 1903, cxxxvi, 699.)

2. Amphibia appear in the Wealden (lower Cretaceous) of Hainault (at Bernissart a village situated between Mons and Tournai, on the frontier of France) in the form of a Urodele, *Hylæobatrachus croyi* DOLLO, 1884. (Bull. Mus roy. Hist. nat. Belg., 1884-5, iii, 91.)

3. Reptiles appear in the lower Lias (lower Jurassic) of Luxembourg (in the suburbs of Arlon, capital of that province) in the form of an Ichthyosaurian, *Ichthyosaurus communis* CONYBEARE, 1822. (Unpublished.)

4. Birds appear in the lower Landénien (lower Eocene) of Hainault (at Mesvin near Mons) in the form of a gigantic wingless relative of the goose, *Gastornis edwardsi* LEMOINE, 1878. (L. DOLLO, Bull. Mus. roy. Hist. nat. Belg. 1883.)

B. Strata in which Belgian fossil Vertebrata are found.

1. *Fishes.* Fossil fishes are found at 26 different geological levels, well correlated stratigraphically. Their description is intrusted to Dr. R. H. Traquair, Honorary Curator of the Edinburgh Museum (pa-

[1] Translated by W. D. MATTHEW, Secretary, Section of Vertebrate Palæontology, International Correlation Committee, National Academy of Sciences.

læozoic and Wealdian fishes), and Dr. M. Leriche, Maître de Conférences of the University of Lille (upper Cretaceous and Tertiary fishes). The complete list of them will be published later.

2. *Amphibia.* Fossil amphibia are at present known only from a single level, the Wealden of Bernissart.

3. *Reptilia.* Fossil reptilia are found at nineteen distinct levels, well correlated stratigraphically. I have personal charge of their study. The principal levels will be considered later in detail.

4. *Birds.* Fossil birds are known from four distinct levels.

5. *Mammals.* Fossil mammals are found at twelve different geological levels. The description of the cetaceans is intrusted to Prof. O. Abel, University of Vienna.

C. Fossil Reptiles of the Jurassic of Belgium.

1. *Ichthyosaurus communis* CONYBEARE, 1822.
   Lower Lias, suburbs of Arlon, in Belgian Luxembourg.
2. *Ichthyosaurus platyodon* CONYBEARE, 1822.
   Middle Lias, Stockem, near Arlon, in Belgian Luxembourg.
3. *Plesiosaurus homalospondylus* OWEN, 1869.
   Middle Lias, Dampicourt, near Virton, Belgian Luxembourg.
4. *Steneosaurus bollensis* JÆGER, 1828.
   Upper Lias, Halanzy, near Messancy, Belgian Luxembourg.

N. B. I have not yet published anything upon these reptiles.

Their occurrence may be tabulated as follows:

LIAS.

Lower	Middle	Upper
1. *Ichthyosaurus communis.*	1. *Ichthyosaurus platyodon.*	1. *Ichthyosaurus* sp.
	2. *Plesiosaurus homalospondylus.*	2. *Plesiosaurus* sp.
		3. *Steneosaurus bollensis.*

D. The Reptiles and Batrachians of the Wealden of Belgium.

Horizon. The Wealden is the fresh-water facies of the Neocomian, which forms the base of the Cretaceous.

CHRONOLOGIC TABLE OF THE MESOZOIC FORMATIONS OF BELGIUM.

Periods & Epochs (world-wide)	*Stages or Formations Belgian series*	*Origin and character of the terranes*	*Characteristic fossils obtained in the terranes*	*Chief features of Belgian Geography*
Cretaceous	**Mæstrichtian**	Marine (*granular limestone; tuff*)	Turtles and marine saurians, fishes, invertebrates, plants	Partial marine invasion.
	Senonian — Spiennes assise	Marine (*Coarse-grained chalk*)	Turtles and marine saurians, fishes, invertebrates, plants	Alternating invasion and retreat of marine waters, of varying extent.
	Senonian — Nouvelles "	Marine (*Pure chalk*)	Fishes, invertebrates	
	Senonian — Obourg "	Marine (*Soft chalk*)		
	Senonian — Trivières "	Marine (*Marly chalk, sand, clay*)		
	Senonian — St. Vaast "	Hainault, marine (*Marly chalk*)	Fishes, invertebrates	
		Limburg, fluvio-marine (*Sand, clay, glauconite*)	Turtles and marine saurians, fishes, marine and fresh-water invertebrates, plants	
	Turonian	Marine (*marl, sand, glauconitic chalk*)	Fish and invertebrates	Marine invasions of varying extent in Western Belgium.
	Cenomanian	Marine (*gravels, marls*)		
	Albian	Marine (*shale, grit*)		
	. . . .	Not represented		All Belgium continental.
	Wealdian	Fluviatile (*Sand and plastic clay*)	Iguanodons, crocodiles, turtles, fishes and plants of Bernissart, plants of Bracquegnies and Beaune	Belgium continental and traversed by an important river.
Jurassic — **Upper**	. . . .	Not represented		All Belgium continental.
Middle	**Bajocian**	Marine (*Limestone*)	Invertebrates	
Lower	**Liassian**	Marine (*Sandstone, shale, schist, marl, limestone*)	Marine reptiles, fishes, invertebrates Marine reptiles, fishes, invertebrates	S.-E. extremity of the country under sea.
Triassic	**Keuperian**	Marine (*Clay, marl, limestone*)	Invertebrates	Marine invasion of the N.-E. part of the country.
	Pœcilian	Marine (*Conglomerates, clay-shales*)	Invertebrates	

A. RUTOT.

Locality. Bernissart, a village of Hainault, between Mons and Tournai, on the frontier of France.

1. *Iguanodon mantelli* von Meyer, 1832.
   Dinosaurian. Type of the genus *Iguanodon* Mantell, 1825. The type of the species is a block from Maidstone (Kent), coming from the Lower Greensand, or Aptian, hence more recent than the Neocomian or Wealdian. It is preserved in the British Museum. This species has been discovered in the Neocomian of Bedfordshire and in the typical Wealden of England (Sussex, Isle of Wight).
   L. Dollo, Bull. Mus. roy. Hist. nat. Belg., 1882, i, 161.

2. *Iguanodon bernissartensis* Boulenger, 1881.
   Dinosaurian. The type of the species is the individual denominated "Q" of the series in the Brussels Museum, from the Wealden of Bernissart. This species has also been found in the Neocomian of Bedfordshire and in the typical Wealden of England (Sussex, Isle of Wight).
   L. Dollo, Bull. Mus. roy. Hist. nat. Belg., 1882, i, 161.

3. *Goniopholis simus* Owen, 1878.
   Crocodilian. The type of the species is a cranium from the middle Purbeck (Upper Jurassic) of Swanage in Dorsetshire, preserved in the British Museum.
   L. Dollo, Bull. Mus. roy. Hist. nat. Belg., 1883, ii, 316.

4. *Bernissartia fagesi* Dollo, 1883.
   Crocodilian. Type of the genus *Bernissartia* Dollo, 1883. The type of the species is from the Wealden of Bernissart and is preserved in the Brussels Museum. This is the first appearance of crocodiles with the modern type of armor, that is to say, with more than two longitudinal series of plates on the back.
   Bull. Mus. roy. Hist. nat. Belg., 1883, ii, 321.

5. *Chitracephalus dumoni* Dollo, 1884.
   Chelonian. Type of the genus *Chitracephalus* Dollo, 1884. The type of the species is from the Wealden of Bernissart and is preserved in the Brussels Museum.
   Bull. Mus. roy. Hist. nat. Belg., 1884, iii, 70.

6. *Peltochelys duchasteli* Dollo, 1884.
   Chelonian. Type of the genus *Peltochelys* Dollo, 1884. The type of the species is from the Wealden of Bernissart and is preserved in the Brussels Museum. It is represented in the Wealden of Sussex by *Tretosternum bakewelli* Mantell, 1833, with which it may prove to be identical.
   Bull. Mus. roy. Hist. nat. Belg., 1884, ii, 78.

7. *Hylæobatrachus croyi* DOLLO, 1884.
Urodele. Type of the genus *Hylæobatrachus* DOLLO, 1884. The type of the species is from the Wealden of Bernissart and is preserved in the Brussels Museum. It is the most ancient known Urodele.
Bull. Mus. roy. Hist. nat. Belg., 1884, iii, 91.

8. *Megalosaurus dunkeri* DAMES 1884.
Dinosaurian. The type of the species is a tooth from the Wealden of Deister, Hanover, and is preserved at the University of Marburg.
L. DOLLO, Comptes rend. Acad. Sci. Paris, 1903, cxxxvi, 565.

E. Reptiles of the Lower Senonian of Belgium.

Horizon. Dark green glauconitic clayey sand forming the base of the Senonian.

Locality. Lonzée, a village of the province of Namur, near Gembloux.

1. *Craspedodon lonzeensis* DOLLO, 1883.
Dinosaurian. Type of the genus *Craspedodon* DOLLO, 1883. The type of the species consists of two teeth from the glauconite of Lonzée, preserved in the Brussels Museum. *Craspedodon* is more specialized than *Iguanodon*.
Bull. Mus. roy. Hist. nat. Belg., 1883, ii, 218.

2. *Megalosaurus lonzeensis* DOLLO, 1903.
Dinosaurian. Referred provisionally to the genus *Megalosaurus*. The type of the species is an ungual phalanx from the glauconite of Lonzée, preserved in the Brussels Museum.
Comptes rend. Acad. Sci. Paris, 1903, cxxxvi, 567.

3. *Mosasaurus lonzeensis* DOLLO, 1904.
Mosasaurian. The type of the species consists of a quadrate bone and caudal vertebræ from the glauconite of Lonzée, preserved in the Brussels Museum.
Bull. Soc. belg. Géol., 1904, xviii, 213.

4. *Hainosaurus lonzeensis* DOLLO, 1904.
Mosasaurian. The type of the species consists of a premaxilla and caudal vertebræ from the glauconite of Lonzée, preserved in the Brussels Museum.
Bull. Soc. belg. Géol., 1904, xviii, 213.

5. *Glaucochelone lonzeensis* DOLLO, 1909.
Chelonian. Type of the genus *Glaucochelone* DOLLO, 1909. The

type of the species is a mandible with long flat symphysis in adaptation to shell-crushing habits; preserved in the Brussels Museum.
Unpublished.

6. *Tomochelone lonzeensis* DOLLO, 1909.
Chelonian. Type of the genus *Tomochelone* Dollo, 1909. The type of the species is a mandible with short symphysis and cutting border in adaptation to soft food; preserved in the Brussels Museum.
Unpublished.

7. *Plesiosaurian* bones.
Limb bones and vertebræ, characteristic but not yet determinable even generically.
L. DOLLO, Bull. Soc. belg. Géol., 1904, xviii, 215.

F. Reptiles of the Upper Senonian of Belgium.

Horizon. Brown phosphatic chalk forming the top of the Senonian.
Localities. Baudour, Ciply, Cuesmes, Mesvin, Saint-Symphorien, Spiennes etc., communes of Hainault, in the neighborhood of Mons.

1. *Mosasaurus lemonnieri* DOLLO, 1889.
Mosasaurian. The type of the species is a skull preserved in the Brussels Museum.
Bull. Soc. belg. Géol., 1889, iii, 278.

2 *Plioplatecarpus houzeaui* DOLLO, 1889.
Mosasaurian. The type of the species is an incomplete skeleton preserved in the Brussels Museum.
Bull. Soc. belg. Géol., 1889, iii, 290.

3. *Hainosaurus bernardi* DOLLO, 1885.
Mosasaurian. Type of the genus *Hainosaurus* DOLLO, 1885. The type of the species is a nearly complete skeleton preserved in the Brussels Museum.
Bull. Mus. roy. Hist. nat. Belg., 1885, iv, 31.

4. *Prognathosaurus solvayi* DOLLO, 1889.
Mosasaurian. Type of the genus *Prognathosaurus* DOLLO, 1889. The type of the species is an incomplete skeleton preserved in the Brussels Museum.

5. *Prognathosaurus giganteus* DOLLO, 1904.
Mosasaurian. The type of the species is an incomplete skeleton preserved in the Brussels Museum.
Bull. Soc. belg. Géol., 1904, xviii, 213.

6. *Allopleuron hoffmanni* GRAY, 1831.
   Chelonian. Type of the genus *Allopleuron* BAUR, 1888. The type of the species is a carapace from the Maestrichtian, in the Camper collection, preserved in the Teyler Museum, Harlem.
   Unpublished.

7. *Glyptochelone suyckerbuyki* UBAGHS, 1879.
   Chelonian. Type of the genus *Glyptochelone* DOLLO, 1903. The type of the species is a carapace from the Maestrichtian, preserved in the Brussels Museum.
   Unpublished.

8. *Plesiosaurus houzeaui* DOLLO, 1909.
   Plesiosaurian. Limb-bones and vertebræ of a Plesiosaurian of gigantic size, preserved in the Brussels Museum.
   Unpublished.

G. Reptiles of the Maestrichtian of Belgium.

Horizon. Maestricht chalk, which forms the uppermost part of our upper Cretaceous. Sometimes regarded as equivalent to the Danian, but this correlation calls for reconsideration.

Localities. Canne, Eben, Sichen, Sussen etc., villages of Belgian Limburg, not far from Maestricht, which is in Dutch Limburg.

1. *Orthomerus dolloi* SEELEY, 1883.
   Dinosaurian. Type of the genus *Orthomerus* SEELEY, 1883. The type of the species consists of a femur and tibia, preserved in the British Museum.
   Quart. Jour. Geol. Soc. London, 1883, xxxix, 248. Recalls the genus Trachodon.
   L. DOLLO, Bull. Mus. roy. Hist. nat. Belg., 1883, ii, 211.

2. *Megalosaurus bredai* SEELEY, 1883.
   Dinosaurian. The type of the species is a femur, preserved in the British Museum.
   H. G. SEELEY, Quart. Jour. Geol. Soc. London, 1883, xxxix, 246.

3. *Mosasaurus giganteus* SÖMMERING, 1816.
   Mosasaurian. Type of the genus *Mosasaurus* CONYBEARE, 1822. The type of the species is the skull described by Cuvier and preserved in the Paris Museum.
   L. DOLLO, Bull. Soc. belg. Géol., 1890, iv, 151.

4. *Plioplatecarpus marshi* Dollo, 1882.
Mosasaurian. Type of the genus *Plioplatecarpus* Dollo, 1882. The type of the species is an incomplete skeleton preserved in the Brussels Museum.
Bull. Mus. roy. Hist. nat. Belg., 1882, i, 64.

5. *Allopleuron hoffmanni* Gray, 1831.
Chelonian. Type of the genus *Allopleuron* Baur, 1888. The type of the species is a carapace from the Maestrichtian in the Camper collection, preserved in the Teyler Museum, Haarlem.
C. Ubaghs, Description géologique et paléontologique du sol du Limbourg, Ruremonde, 1879, 272.

6. *Glyptochelone suyckerbuyki* Ubaghs, 1879.
Chelonian. Type of the genus *Glyptochelone* Dollo, 1903. The type of the species is a carapace from the Maestrichtian, preserved in the Brussels Museum.
L. Dollo, Bull. Acad. roy. Belg., 1903, 838.

7. *Platychelone emarginata* Dollo, 1909.
Chelonian. Type of the genus *Platychelone* Dollo, 1908. The type of the species is a carapace, preserved in the Brussels Museum. Unpublished.

Recapitulation of the Reptiles and Batrachians of the Cretaceous of Belgium.

Orders of Reptiles and Amphibians	1 Bernissart (Hainault) L'r Cretaceous Wealden Fresh-water	2 Lonzée (Namur) Up'r Cretaceous L'r Senonian Marine	3 Mons (Hainault) Up'r Cretaceous Up'r Senonian Marine	4 Maestricht Limburg Up'r Cretaceous Maestrichtian Marine
1. **Dinosaurians**	×	×	O	×
2. **Crocodilians**	×	O	O	O
3. **Chelonians**	×	×	×	×
4. **Mosasaurians**	O	×	×	×
5. **Plesiosaurians**	O	×	×	O
6. **Rhynchocephalians**	O	O	O	O
7. **Ichthyosaurians**	O	O	O	O
8. **Pterosaurians**	O	O	O	O
9. **Urodeles**	×	O	O	O

Mosasaurus CONYBEARE, 1822.	*Plioplatecarpus* DOLLO, 1882.
Swimming Mosasaur.	Diving Mosasaur.
Surface.	Depths.
Size up to 15 meters.	Size up to 5 meters.
1. Teeth strong.	1. Teeth weak.
2. Orbits lateral.	2. Orbits facing upwards.
3. Parietal foramen reduced.	3. Parietal foramen well developed.
4. Tympanic membrane delicate.	4. Tympanic membrane calcified.
5. No median basioccipital canal.	5. A median basioccipital canal.
6. Thorax long.	6. Thorax short.
7. Caudal fin powerful.	7. Caudal fin weak.
8. Anterior paddles small.	8. Anterior paddles strong.

L. DOLLO, Bull. Soc. belg. Géol., 1904, xviii, 207; *ibid.* 1905, xix, 125.

The calcified tympanic membrane of *Plioplatecarpus* is an adaptation for resisting the temporary heavy pressure of the water at great depths. A different arrangement, but serving the same purpose, is seen among the Cetacea, which are able to dive to 1000 meters below the surface.

The median basioccipital canal of *Plioplatecarpus* is an adaptation to protect the large arterial trunks supplying the cerebral circulation from the temporary heavy pressure at great depths. A different arrangement, serving the same purpose, is found among the Cetacea.

In *Mosasaurus* the caudal neurapophyses (spines) and hæmapophyses (chevrons) are long, the latter being coossified with the vertebrae (centra). In *Plioplatecarpus* the caudal neurapophyses and hæmapophyses are short and the latter are separate from the vertebræ (centra).

Provisional Correlations.

1. *Iguanodon* (Lower Cretaceous) corresponds best with *Claosaurus* (Upper Cretaceous).
2. *Mosasaurus* corresponds with *Clidastes*.
   Hainosaurus " " *Tylosaurus*.
   Prognathosaurus " " *Platecarpus*.
   Plioplatecarpus " " ?
3. *Orthomerus* (Maestrichtian) corresponds best with *Trachodon* (Laramie), but *Champsosaurus* has already appeared in the Laramie in North America, while in Belgium it does not appear until the Lower Eocene.
4. The upper Senonian witnessed the culmination of the Mosasaurs in Belgium, since there were at that time four contemporaneous genera while in the Lower Senonian there were but two, and the same number in the Maestrichtian.

5. The genus *Mosasaurus* has the longest geological range, from the lower Senonian to the upper Maestrichtian; *Plioplatecarpus* survives from upper Senonian to lower Maestrichtian; *Hainosaurus* from lower to upper Senonian, and *Prognathosaurus* is limited to the upper Senonian.
6. In the Maestrichtian two genera of *Mosasaurs* survive, but the Ichthyosaurs and even the Plesiosaurs are wholly extinct. On the other hand there were still, on dry land, herbivorous and carnivorous Dinosaurs.

Bibliography of the Belgian Mosasaurs.

1. From 1882–1904 see:
L. Dollo, Bull. Soc. belg. Géol., 1904, xviii, 216.
2. In 1904: Ibid., pp. 207, 217.
3. In 1905: Ibid., xix, 125.

Part II. Tertiary.

A. Paleocene — Montian.

1. Mammals . . . . . . ×
2. Birds . . . . O
3. Reptiles . . . . ×
4. Amphibians . . . . . O
5. Fishes . . . . ×

Montian { ? Upper . . . . . . Neighborhood of Binche (Hainault).
Montian { Lower . . . . Neighborhood of Mons (Hainault).

Upper Montian.

1. *Coryphodon eocænus* Owen, 1846. Trieu-de-Leval (near Binche).
2. *Trionyx levalensis* Dollo, 1909. Trieu-de-Leval (near Binche). Unpublished.

Lower Montian.

1. Fishes. Six species from Ciply (near Mons) and from Mons.
M. Leriche, Mém. Mus. roy Hist. nat. Belg., 1902, II, No. 1.

B. Lower Eocene — Heersian.

1. Mammals . . . . . . O
2. Birds . . . . O
3. Reptiles . . . . ×

4.	Amphibians	O
5.	Fish	×

Heersian { 2. Marls of Gelinden (Limburg).
1. Sands of Orp-le-Grand (Brabant).

Sands of Orp-le-Grand.

1. *Champsosaurus lemoinei* GERVAIS, 1877. Orp-le-Grand (near Jodoigne).
L. DOLLO, Bull. Soc. belg. Géol., 1890, iv, 55.
2. Fishes. Twenty-three species from Orp-le-Grand (near Jodoigne).
M. LERICHE, Mém. Mus. roy. Hist. nat. Belg., 1902, ii, No. 1.

Marls of Gelinden.

1. Fishes. Five species. (M. LERICHE *loc. cit.*)

C. Lower Eocene — Lower Landenian.

1.	Mammals	O
2.	Birds	×
3.	Reptiles	×
4.	Amphibia	O
5.	Fishes	×

1. *Gastornis edwardsi* LEMOINE, 1878. Mesvin, near Mons (Hainault).
L. DOLLO, Bull. Mus. roy. Hist. nat. Belg., 1883, ii, 297.
2. *Champsosaurus lemoinei* GERVAIS, 1877. Erquelinnes (Hainault), near Maubeuge, France.
L. DOLLO, Bull. Mus. roy. Hist. nat. Belg., 1884, iii, 151.
3. *Eosuchus lerichei* DOLLO, 1907. Jeumont (Nord, France), on the Belgian frontier, in the immediate extension of the Erquelinnes beds.
Bull. Soc. belg. Géol., 1907, xxi, 81.
4. *Lytoloma gosseleti* DOLLO, 1886. Erquelinnes (Hainault), near Maubeuge.
Bull. Mus. roy. Hist. nat. Belg., 1886, iv, 129.
5. *Argillochelys antiqua* KÖNIG, 1825 . . . Erquelinnes (Hainault).
L. DOLLO, Bull. Soc. belg. Géol., 1907, xxi, 81.
6. Fishes. Twenty-nine species from Erquelinnes and elsewhere in Belgium.
M. LERICHE, Mém. Mus. roy. Hist. nat. Belg., 1902, ii, No. 1.

CHRONOLOGIC TABLE OF THE CENOZOIC FORMATIONS OF BELGIUM.

Periods and Epochs (world-wide)			Stages or Formations Belgian series		Origin and Character of the terranes	Characteristic Fossils obtained in the terranes.	Chief Features of Belgian Geography.
Quaternary	Recent				Marine (*sand and clay*); fluviatile (*alluvium*); terrestrial (*peat*)	Oxen, Deer, Boars etc., and mollusks	Modern geographic conditions.
	Pleistocene	Upper	Upper		Marine (*sand*) and fluviatile (*mud*)	Mammoth, Rhinoceros, Reindeer, then Reindeer alone	Belgium partly invaded by the sea.
		Middle	Middle		Fluviatile (*sand and mud*)	Mammoth, Rhinoceros, Reindeer etc., insects, mollusks and plants	Belgium continental with large rivers.
		Lower	Lower		Fluviatile (*gravel, sand, loam*)	*Elephas antiquus*, Hippopotamus etc., plants	Belgium continental, rivers large.
Tertiary	Pliocene	Upper	Amstelian		Marine (*sand*)		Repeated marine invasions in the North of Belgium.
		Middle	Poederlian	Upper	Fluvio-marine (*sand, clay, lignite*)	Marine and terrestrial mammals, plants	
				Lower	Marine (*sand*)	Marine mollusks	
		Lower	Scaldisian		Marine (*sand*)	Whalebone whales, fishes, mollusks, etc.	
			Diestian		Marine (*sand*)	Whalebone whales, seals, fishes, mollusks	
	Miocene		Bolderian		Marine (*sand*)	Sirenians, dolphins, turtles, fishes, mollusks	The North of Belgium under the sea.
			(not represented)		Terrestrial		
	Oligocene	Upper	Aquitanian		Marine (*sand*) and lacustrine (*clay*)	Mollusks, plants	Great marine invasion in the East of Belgium.
		Middle	Rupelian	Upper	Marine (*clay*)	Sirenians, turtles, fishes, mollusks	Marine invasion in the North of Belgium.
				Lower	Marine (*sand and clay*)	Fishes and mollusks	
		Lower	Tongrian	Upper	Fluvio-marine (*sand, clay, marl*)	Brackish water mollusks	Marine invasion in the North of Belgium.
				Lower	Marine (*sand*)	Fishes and marine mollusks	
	Eocene	Upper	Asschian		Marine (*sand, clay*)	Fishes and mollusks	Marine invasions in the North-west of Belgium.
			Wemmelian		Marine (*sand*)	Turtles, fishes, mollusks, Nummulites	
		Middle	Ledian		Marine (*calcareous sand*)	Fishes, mollusks, Nummulites	Marine invasions in the West of Belgium.
			Laekenian		Marine (*calcareous sand*)	Mammals, fishes, mollusks, Nummulites	
			Bruxellian		Marine (*sand and calcareous sand*)	Birds, turtles, fishes, mollusks, plants	A deep gulf in the central part of Belgium.
		Lower	Paniselian	Upper	Marine (*sand*)	Fishes, mollusks etc.	The North-west of Belgium under the sea.
				Lower	Marine (*sand, clay*)	Turtles, fishes, mollusks etc., plants	The West of Belgium under the sea.
			Ypresian		Marine (*sand, clay*)	Turtles, fishes, mollusks, Nummulites	Lower and Middle Belgium invaded by the sea.
			Landenian	Upper	Fluvio-marine (*sand, clay, lignite*)	Mammals, turtles, crocodiles, fishes, plants, fossil resin	Enormous fluviatile development in Belgium.
				Lower	Marine (*sand, clay*)	Birds, turtles, crocodiles, fishes, mollusks	Great marine invasion.
			Heersian		Marine (*sand, clay*)	Fishes, mollusks, plants	North-eastern Belgium under the sea.
	Paleocene		Montian	Upper	Fluvio-marine, lacustrine (*plastic clay, lignite*)	Mammals, turtles, fresh-water mollusks, plants, fossil resin	Belgium continental.
				Lower	Marine (*granular chalk, tuff*)	Fishes, invertebrates	Slight invasion of the sea in Hainault.

A. Rutot

D. Lower Eocene — Upper Landenian.

1.	Mammals	×
2.	Birds	○
3.	Reptiles	×
4.	Amphibia	○
5.	Fishes	×

Erquelinnes.

(Hainault, Belgium), near Maubeuge, (Nord, France)

1. *Coryphodon eocænus* OWEN, 1846. Erquelinnes.
   Identification by Dollo. Unpublished.
2. *Pachynolophus maldani* LEMOINE, 1878. Erquelinnes.
   A. RUTOT, Bull. Acad. roy. Belg., 1881, i, 536.
3. *Hyænodictis* (= *Dissacus* auct. Thèvenin) sp. Erquelinnes.
   Identification by Osborn. Unpublished.
4. *Didymictis* sp. indet. Erquelinnes.
   Identification by Thèvenin. Unpublished.
5. *Crocodilus depressifrons* BLAINVILLE, 1855. Erquelinnes.
   L. DOLLO, Bull. Soc. belg. Géol., 1907, xxi, 81.
6. *Trionyx vittatus* POMEL, 1847. Erquelinnes.
   Ibid.
7. *Trionyx henrici* OWEN, 1849. Erquelinnes.
   Ibid.
8. *Trionyx erquelinnensis* DOLLO, 1909. Grand-Reng near Erquelinnes.
   Unpublished.
9. *Amia barroisi* LERICHE, 1900. Erquelinnes.
   M. LERICHE, Mém. Mus. roy. Hist. nat. Belg., 1902, ii, No. 1.
10. *Amia* sp. indet. Erquelinnes.
    Ibid.
11. *Lepidosteus suessoniensis* GERVAIS, 1852. Erquelinnes.
    Ibid.

Orsmael.

North of Landen in Hesbaye (Belgium).

1. *Phenacodus* sp. indet. Orsmael.
   Identification by Thèvenin.
2. *Stypolophus* sp. indet. Orsmael.
   Identification by Thèvenin.

3. *Plesiadapis* sp. indet. Orsmael.
   Identification by Thèvenin.
4. *Decticadapis* sp. indet. Orsmael.
   Identification by Thèvenin.
5. Creodont sp. indet. Orsmael.
   Identification by Thèvenin.
6. *Amia barroisi* LERICHE, 1900. Orsmael.
   Mém. Mus. roy. Hist. nat. Belg., 1902, ii, No. 1.
7. *Lepidosteus suessoniensis* GERVAIS, 1852. Orsmael.
   M. LERICHE, *loc. cit.*

E. Lower Eocene. Ypresian.

1.	Mammals	O
2.	Birds	O
3.	Reptiles	×
4.	Amphibia	O
5.	Fishes	×

1. *Eosphargis gigas* OWEN, 1860. Quenast (Brabant).
   Skeleton, nearly complete, of a gigantic marine thecophore chelonian.
   The typical carapace is very much reduced, a true ancestral stage of *Dermochelys* (*Sphargis*) and its allies. First discovered in the London Clay (equivalent of the Ypresian) of the Isle of Sheppey, at the mouth of the Thames.
   L. DOLLO, Bull. Soc. belg. Géol., 1907, xxi, 81.
2. Fishes. Thirty-seven species of cartilaginous and bony fishes.
   M. LERICHE, Mém. Mus. roy. Hist. nat. Belg., 1905, iii, No. 3.

F. Lower Eocene. Paniselian.

1.	Mammals	O
2.	Birds	O
3.	Reptiles	×
4.	Amphibia	O
5.	Fishes	×

1. Chelonians. Fragments not yet identified.
2. Fishes. Twenty-four species of cartilaginous and bony fishes.
   M. LERICHE, loc. cit.

G. Middle Eocene. Bruxellian.

1.	Mammals	O
2.	Birds	×
3.	Reptiles	×
4.	Amphibia	O
5.	Fishes	×

1. *Argillornis longipennis* OWEN, 1878. Etterbeek near Brussels.
   A frigate-bird of large size. Unpublished.
2. *Palæophis typhæus* OWEN, 1850. Brussels.
   A marine serpent. Unpublished.
3. *Pseudotrionyx delheidi* DOLLO, 1886. Melsbroek near Vilvorde (Brabant).
   A turtle of the family Chelydridæ. Found, like the two preceding, in the London Clay, which, however, is equivalent (in part) to the Ypresian.
   Bull. Mus. roy. Hist. nat. Belg., 1886, iv, 75.
4. *Emys camperi* GRAY, 1831. Melsbroek near Vilvorde (Brabant).
   A marsh turtle.
   T. C. WINKLER, Arch, Mus. Teyler, 1869, ii, 127.
5. *Testudo houzei* DOLLO, 1909. Saventhem near Brussels.
   Unpublished.
6. *Eochelone brabantica* DOLLO, 1903. Saint-Remy-Geest (Brabant).
   A marine turtle adapted to eating soft food.
   Bull. Acad. roy. Belg., 1903.
7. *Lytoloma bruxelliensis* DOLLO, 1909. St. Josse-ten-Noode, near Brussels.
   A marine turtle adapted to shell crushing.
8. *Trionyx bruxelliensis* WINKLER, 1869. Brussels.
   T. C. WINKLER, Arch. Mus. Teyler, 1869, ii, 135.
9. Fishes. Sixty-two species of cartilaginous and bony fishes.
   M. LERICHE, Mém. Mus. roy. Hist. nat. Belg., 1905, iii, No. 3.

H. Middle Eocene. Lækenian.

1.	Mammals	×
2.	Birds	O
3.	Reptiles	O
4.	Amphibia	O
5.	Fishes	×

1. *Lophiotherium cervulum* GERVAIS, 1849. St. Gilles near Brussels.
   Identification by Gaudry.
   A. RUTOT, Bull. Acad. roy. Belg., 1881, i, 546.
2. Fishes. Fifty-four species of cartilaginous and bony fishes.
   M. LERICHE, Mém. Mus. roy. Hist. nat. Belg., 1905, iii, No. 3.

I. Middle Eocene. Ledien.

1.	Mammals	O
2.	Birds	O
3.	Reptiles	O
4.	Amphibia	O
5.	Fishes	×

1. Fishes. Twelve species of cartilaginous and bony fishes.
   M. LERICHE, *loc. cit.*

J. Upper Eocene. Wemmelian.

1.	Mammals	O
2.	Birds	O
3.	Reptiles	×
4.	Amphibia	O
5.	Fishes	×

1. *Lytoloma wemmeliensis* DOLLO, 1909. Locality not known.
   A marine shell-crushing turtle.
   Unpublished.
2. Fishes. Nineteen species of cartilaginous and bony fishes.
   M. LERICHE, *op. cit.*

K. Upper Eocene. Asschian.

1.	Mammals	O
2.	Birds	O
3.	Reptiles	O
4.	Amphibia	O
5.	Fishes	×

1. Fishes. Seven species of cartilaginous and bony fishes.
   M. LERICHE, *op. cit.*

L. Lower Oligocene. Tongrian.

1.	Mammals	O
2.	Birds	O
3.	Reptiles	O
4.	Amphibia	O
5.	Fishes	×

1. Fishes. List in memoir now in press.
M. Leriche, Mém. Mus. roy. Hist. nat. Belg., 1909, v, No. 2.

M. Middle Oligocene. Rupelian.

1.	Mammals	×
2.	Birds	×
3.	Reptiles	×
4.	Amphibia	O
5.	Fishes	×

1. *Rhinoceros.* Species not yet determined. Boom (province of Antwerp).
A mandible.
Unpublished; will be described by a student of Brussels University.
2. *Halitherium schinzi* Kaup, 1838. Boom (province of Antwerp).
Several skeletons more or less complete of this sirenian.
Unpublished.
3. *Rupelornis definitus* Van Ben., 1871. Rupelmonde (eastern Flanders).
Bull. Acad. roy. Belg., 1871, xxxii, 258.
4. *Vanellus selysi* Van Beneden, 1871. Rupelmonde (eastern Flanders).
Op. cit. p. 259.
5. *Anas creccoides* Van Beneden, 1871. Rupelmonde (eastern Flanders).
Op. cit. p. 260.
6. *Psephophorus rupeliensis* Van Beneden, 1883. Niel near Boom (prov. Antwerp).
A gigantic marine leathery turtle, the oldest of the *Dermochelys* (*Sphargis*) group thus far known in Belgium.
Op. cit., 1883, vi, 666.
L. Dollo, Bull. Mus. roy. Hist. nat. Belg., 1888, v, 59.
8. *Bryochelys waterkeyni* Van Beneden, 1871. Boom (prov. Antwerp).
A small marine typical (thecophore) turtle.
Bull. Acad. Roy. Belg., 1871, xxxi, 12.
9. *Chelyopsis littoreus* Van Beneden, 1886. Boom (prov. Antwerp).
A large marine typical (thecophore) turtle.
G. Smets, Annal. Soc. scientif. Bruxelles, 1886, x, 12.

10. *Chelone vanbenedeni* Smets, 1886. Boom (prov. Antwerp).
    A marine typical (thecophore) turtle.
    G. Smets, *op. cit.*, p. 109.
11. *Oligochelone rupeliensis* Dollo, 1909. Niel near Boom (prov. Antwerp).
    Complete carapace and limb-bones of a marine typical turtle.
    Unpublished.
12. Fishes. Very rich ichthyic fauna, which, besides the numerous cartilaginous fishes, includes numerous Scombridæ. List in a memoir now in press.
    M. Leriche, Mém. Mus. roy. Hist. nat. Belg., 1909, v, No. 2.

N. Upper Oligocene. Aquitanian.

1.	Mammals	O
2.	Birds	O
3.	Reptiles	O
4.	Amphibia	O
5.	Fishes	O

O. Upper Miocene. Bolderian.

1.	Mammals	×
2.	Birds	×
3.	Reptiles	×
4.	Amphibia	O
5.	Fishes	×

1. *Miosiren kocki* Dollo, 1889. Boom (prov. Antwerp).
   Skeleton of an enormous sirenian, very interesting in the simplification of its last molar, which marks a tendency toward the conditions shown in *Halicore*.
   Bull. Soc. belg., Geol., 1889, iii, 415.
2. *Prophoca rousseaui* Van Beneden, 1876. Pinniped. Borsbeeck and Vieux-Dieu, near Antwerp.
   Annal. Mus. roy. Hist. nat. Belg., 1877, i, 79.
3. *Prophoca proxima* Van Beneden, 1876. Pinniped. Borgerhout and Vieux-Dieu, near Antwerp.
   Op. cit., p. 80.
4. *Squalodon antwerpiensis* Van Beneden, 1865. Odontocete. Near Antwerp.
   O. Abel, Mém. Mus. roy. Hist. nat. Belg., 1905, iii, No. 2.

5. *Scaldicetus caretti* du Bus, 1867. Odontocete. Near Antwerp. O. Abel, *op. cit.*
6. *Scaldicetus grandis* du Bus, 1872. Odontocete. Near Antwerp. O. Abel, *op. cit.*
7. *Scaldicetus mortselensis* du Bus, 1872. Odontocete. Near Antwerp. O. Abel, *op. cit.*
8. *Thalassocetus antwerpensis* Abel, 1905. Odontocete. Near Antwerp. O. Abel, *op. cit.*
9. *Physeterula dubusi* Van Beneden, 1877. Odontocete. Near Antwerp. O. Abel, *op. cit.*
10. *Prophyseter dolloi* Abel, 1905. Odontocete. Near Antwerp. O. Abel, *op. cit.*
11. *Placoziphius duboisi* Van Ben., 1869. Odontocete. Near Antwerp. O. Abel, *op. cit.*
12. *Palæoziphius scaldensis* du Bus, 1872. Odontocete. Near Antwerp. O. Abel, *op. cit.*
13. *Cetorhynchus atavus* Abel, 1905. Odontocete. Near Antwerp. O. Abel, *op. cit.*
14. *Mioziphius belgicus* Abel, 1905. Odontocete. Near Antwerp. O. Abel, *op. cit.*
15. *Choneziphius planirostris* Cuvier, 1823. Odontocete. Near Antwerp. O. Abel, *op. cit.*
16. *Mesoplodon longirostris* Cuvier, 1823. Odontocete. Near Antwerp. O. Abel, *op. cit.*
17. *Eurhinodelphis cocheteuxi* du B., 1867. Odontocete. Near Antwerp. O. Abel, *op. cit.*
18. *Eurhinodelphis longirostris* du Bus, 1872. Odontocete. Nr Antwerp. O. Abel: *op. cit.*
19. *Eurhinodelphis cristatus* du Bus, 1872. Odontocete. Near Antwerp. O. Abel: *op. cit.*
20. *Cyrtodelphis sulcatus* Gervais, 1853. Odontocete. Near Antwerp. O. Abel: *op. cit.*
21. *Acrodelphis scheynensis* du Bus, 1872. Odontocete. Near Antwerp. O. Abel, *op. cit.*
22. *Acrodelphis macrospondylus* Abel, 1905. Odontocetes. Nr Antwerp. O. Abel: *op. cit.*
23. *Acrodelphis denticulatus* Probst, 1886. Odontocete. Near Antwerp. O. Abel: *op. cit.*
24. *Protophocaena minima* Abel, 1905. Odontocete. Near Antwerp. O. Abel, *op. cit.*
25. *Pithanodelphis cornutus* du Bus, 1872. Odontocete. Near Antwerp. O. Abel, *op. cit.*

26. *Erpetocetus scaldiensis* Van Ben., 1872. Mysticete. Near Antwerp.
P. J. Van Beneden, Ann. Mus. roy. Hist. nat. Belg., 1882, vii, 84.
27. *Mesocetus longirostris* Van Ben., 1880. Mysticete. Near Antwerp.
Op. cit., 1886, xiii, 43.
28. *Mesocetus pinguis* Van Beneden, 1880. Mysticete. Near Antwerp.
Op. cit., p. 50.
29. *Mesocetus latifrons* Van Beneden, 1880. Mysticete. Near Antwerp.
Op. cit., p. 56.
30. *Idiocetus laxatus* Van Beneden, 1880. Mysticete. Near Antwerp.
Op. cit., p. 63.
31. *Idiocetus longifrons* Van Beneden, 1880. Mysticete. Near Antwerp.
Op. cit., p. 73.
32. *Isocetus depauwi* Van Beneden, 1880. Mysticete. Near Antwerp.
Op. cit., p. 78.
33. *Fulica dejardini* Van Beneden, 1871. Bird. Near Antwerp.
Bull. Acad. roy. Belg., 1871, xxxii, 261.
34. *Anser scaldii* Van Beneden, 1873. Bird. Near Antwerp.
Patria Belgica, 1873, i, 372.
35. *Cygnus herenthalsi* Van Beneden, 1873. Bird. Near Antwerp.
Op. cit.
36. *Psephophorus scaldii* Van Beneden, 1871. Near Antwerp.
Marine leathery turtle of the Dermochelys (Sphargis) group, the most gigantic known, surpassing even the *Colossochelys atlas* in size.
L. Dollo, Bull. Mus. roy. Hist. nat. Belg., 1888, v, 75.
37. Fishes. The list of these will be published later in the Memoirs of the Royal Belgian Museum by M. Leriche.

P. Lower Pliocene. Diestian.

1.	Mammals	×
2.	Birds	○
3.	Reptiles	○
4.	Amphibia	○
5.	Fishes	×

1. *Monatherium delognei* Van Ben., 1876. Pinniped. Near Antwerp.
Ann. Mus. roy. Hist. nat. Belg., 1877, i, 75.
2. *Monatherium affine* Van Ben., 1876. Pinniped. Near Antwerp.
Op. cit., p. 76.
3. *Monatherium aberratum* Van Ben., 1876. Pinniped. Near Antwerp.
Op. cit., p. 77.

4. *Plesiocetus brialmonti* VAN BEN., 1880. Mysticete. Near Antwerp. *Op. cit.*, 1885, ix, 12.
5. *Plesiocetus dubius* VAN BENEDEN, 1872. Mysticete. Near Antwerp. *Op. cit.*, p. 21.
6. *Plesiocetus hupschi* VAN BENEDEN, 1859. Mysticete. Near Antwerp. *Op. cit.*, p. 29.
7. *Plesiocetus burtini* VAN BENEDEN, 1859. Mysticete. Near Antwerp. *Op. cit.*, p. 35.
8. *Amphicetus later* VAN BENEDEN, 1880. Mysticete. Near Antwerp. *Op. cit.*, 1886, xiii, 3.
9. *Amphicetus verus* VAN BENEDEN, 1880. Mysticete. Near Antwerp. *Op. cit.*, p. 8.
10. *Amphicetus editus* VAN BENEDEN, 1880. Mysticete. Near Antwerp. *Op. cit.*, p. 13.
11. *Amphicetus rotundus* VAN BEN., 1880. Mysticete. Near Antwerp. *Op. cit.*, p. 18.
12. *Heterocetus affinis* VAN BEN., 1880. Mysticete. Near Antwerp. *Op. cit.*, p. 24.
13. *Heterocetus brevifrons* VAN BEN., 1872. Mysticete. Near Antwerp. *Op. cit.*, p. 31.
14. *Heterocetus sprangi* VAN BENEDEN, 1886. Mysticete. Near Antwerp. *Op. cit.*, p. 36.
15. Fishes. The list of these will be published later in the Memoirs of the Royal Belgian Museum by M. Leriche.

Q. Middle Pliocene (first phase). Scaldisian.

1.	Mammals	×
2.	Birds	O
3.	Reptiles	×
4.	Amphibia	O
5.	Fishes	×

1. *Trichechodon konincki* VAN BEN., 1871. Pinniped. Near Antwerp. Ann. Mus. roy. Hist. nat. Belg., 1877, i, 46.
2. *Alachtherium cretsi* DU BUS, 1867. Pinniped. Near Antwerp. *Op. cit.*, p. 50.
3. *Mesotaria ambigua* VAN BENEDEN, 1876. Pinniped. Near Antwerp. *Op. cit.*, p. 56.
4. *Palæophoca nysti* VAN BENEDEN, 1859. Pinniped. Near Antwerp. *Op. cit.*, p. 60.

5. *Callophoca obscura* Van Beneden, 1876. Pinniped. Near Antwerp. *Op. cit.*, p. 65.
6. *Platyphoca vulgaris* Van Beneden, 1876. Pinniped. Near Antwerp. *Op. cit.*, p. 67.
7. *Gryphoca similis* Van Beneden, 1876. Pinniped. Near Antwerp. *Op. cit.*, p. 69.
8. *Phocanella pumila* Van Beneden, 1876. Pinniped. Near Antwerp. *Op. cit.*, p. 70.
9. *Phocanella minor* Van Beneden, 1876. Pinniped. Near Antwerp. *Op. cit.*, p. 71.
10. *Phoca vitulinoides* Van Beneden, 1871. Pinniped. Near Antwerp. *Op. cit.*, p. 72.
11. *Balænula balænopsis* Van Beneden, 1872. Mysticete. Near Antwerp. *Op. cit.*, 1880, iv, 52.
12. *Balæna primigenia* Van Beneden, 1872. Mysticete. Near Antwerp. *Op. cit.*, p. 66.
13. *Balænotus insignis* Van Beneden, 1872. Mysticete. Near Antwerp. *Op. cit.*, p. 71.
14. *Megaptera affinis* Van Beneden, 1882. Mysticete. Near Antwerp. *Op. cit.*, 1882, vii, 39.
15. *Balænoptera sibbaldina* Van Ben., 1880. Mysticete. Near Antwerp. *Op. cit.*, p. 63.
16. *Balænoptera musculoides* Van Ben., 1880. Mysticete. Near Antwerp. *Op. cit.*, p. 65.
17. *Balænoptera borealina* Van Ben., 1880. Mysticete. Near Antwerp. *Op. cit.*, p. 71.
18. *Balænoptera rostratella* Van Ben., 1880. Mysticete. Near Antwerp. *Op. cit.*, p. 73.
19. *Burtinopsis similis* Van Beneden, 1872. Mysticete. Near Antwerp. *Op. cit.*, p. 77.
20. *Burtinopsis minutus* Van Beneden, 1880. Mysticete. New Antwerp. *Op. cit.*, p. 80.
21. *Psephophorus scaldii* Van Beneden, 1871. Near Antwerp.
    A marine leathery turtle of the *Dermochelys* (*Sphargis*) group, and the most gigantic known, surpassing even *Colossochelys atlas* in size.
    L. Dollo: Bull. Mus. roy. Hist. nat. Belg., 1888, v, 80.
22. Fishes. The list of these will be published later in the memoirs of the Royal Belgian Museum by M. Leriche.

R. Middle Pliocene (second phase). Pœderlian.

1. Mammals . . . . . . ×
2. Birds . . . . O
3. Reptiles . . . . O
4. Amphibia . . . . . . O
5. Fishes . . . . ×

1. *Rhinoceros* (species not yet determined). Near Antwerp.
   Unpublished.
2. *Cervus falconeri* BOYD-DAWKINS, 1868.
   Ryckevoorsel, in the Antwerp country.
   E. DUBOIS, Bull. Soc. belg. Géol., 1905, xix, 121.
3. *Alachtherium antwerpiensis* HASSE, 1909. Near Antwerp.
   An undescribed fossil walrus which will be published by a student of Brussels University. Its milk dentition agrees with that of terrestrial carnivora, and its adult dentition to the milk dentition of the living walrus (Dollo).
4. *Cetorhinus maximus* GUNNER, 1765. Near Antwerp.
   A splendid complete branchial apparatus of this shark.
   M. LERICHE, Comptes rend. Acad. Sci. Paris, 1908, cxlvi, 875.

S. Upper Pliocene. Amstelian.

1. Mammals . . . . . . O
2. Birds . . . . O
3. Reptiles . . . . O
4. Amphibia . . . . . . O
5. Fishes . . . . O

PLATE VII.

Mosasaurus *Conybeare,* 1822.

A Surface-Swimming Mosasaurian.

Lower Senonian to Upper Maestrichtian.

The environment and pose of the animal are copied from Williston's restoration, while the proportions and form of the various parts of the body and paddles are restored directly from the *Mosasaurus lemonnieri* Dollo, 1889, thus facilitating a comparison of the restorations. We may note also the elimination of the bifid tongue, which does not exist in living marine reptiles and is therefore not in accordance with the pelagic adaptation of the animal.

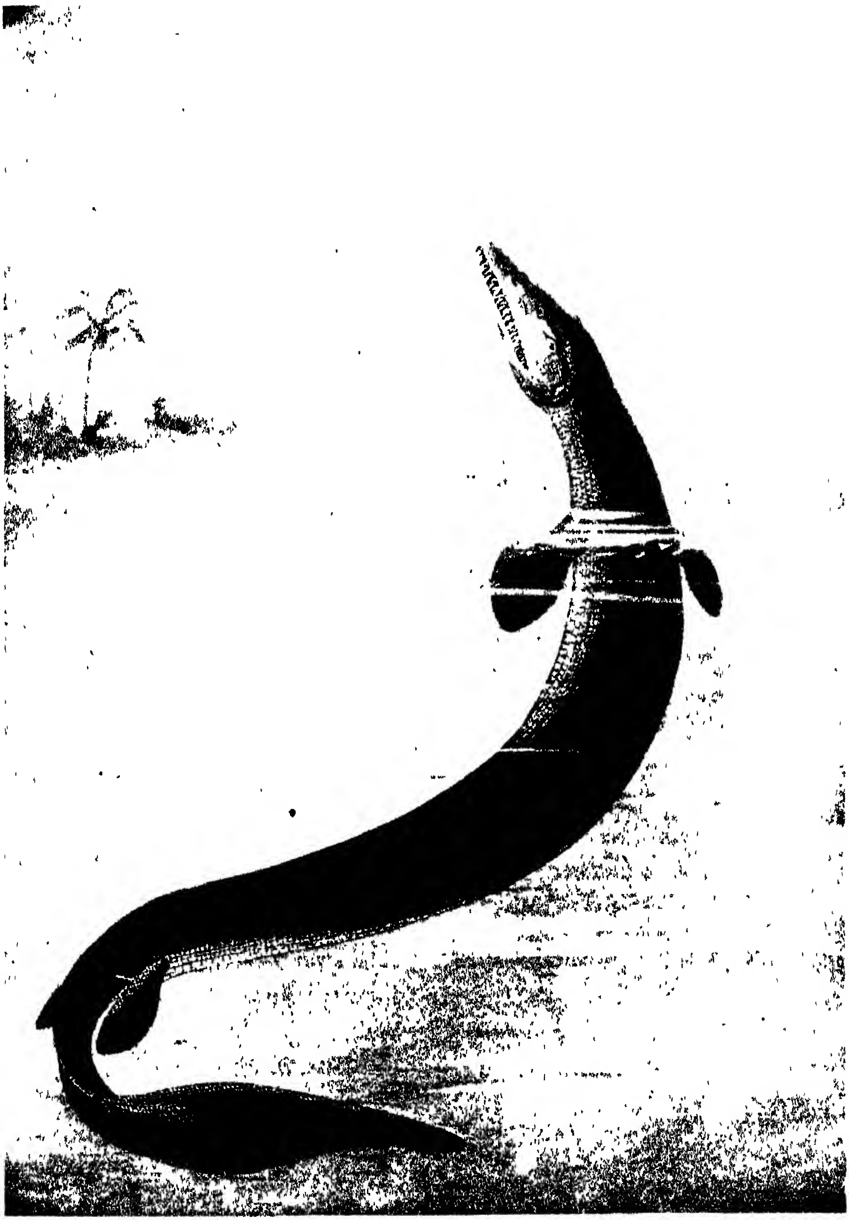


PLATE VIII.

PLIOPLATECARPUS *Dollo*, 1882.

A deep-diving Mosasaurian.
Upper Senonian to Lower Maestrichtian.

PLATE IX.

MOSASAURUS GIGANTEUS *Sommering*, 1816.

Left quadrate, external side, natural size. Canne (Belgian Limbourg) near Maestricht. Upper Cretaceous (Maestrichtian); original in Brussels Museum. L. DOLLO: Bull. Soc. belg. Géol., 1890, IV, pl. viii, fig. 1.

Showing the tympanic groove (r. tymp.), indicating a delicate tympanic membrane, and hence a surface-swimming habitat.

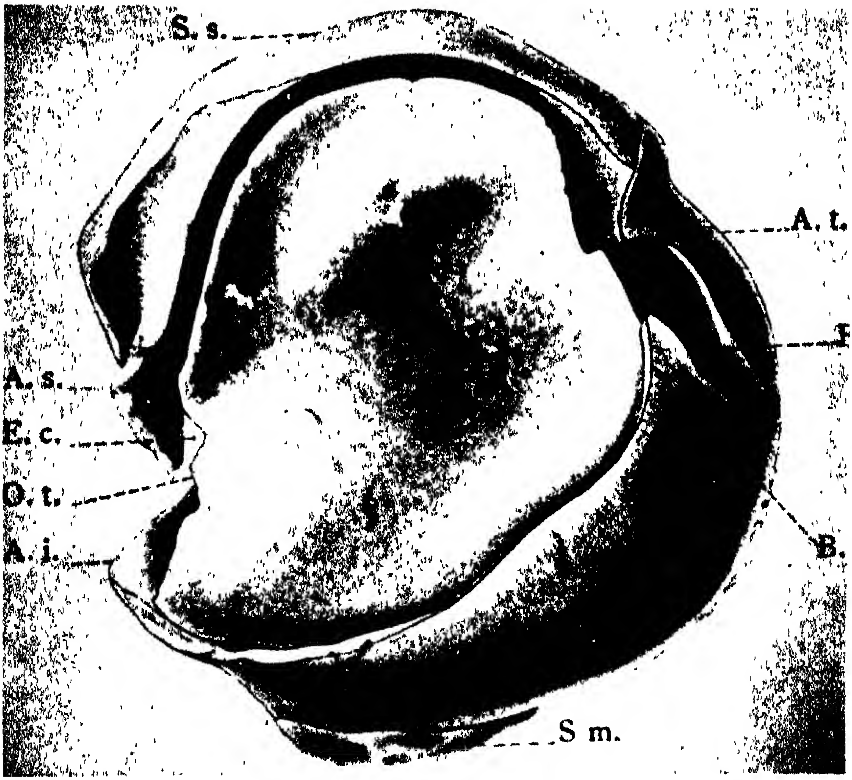

s. art.
s. art.
b tymp.
ap. sup
éch. c
éch. co
A
ap. supr.
B
t. infr.
ap gr
r tymp.
cr. m. ob.
s. art. inf

PLATE X.

PLIOPLATECARPUS HOUZEAUI *Dollo,* 1889.

Right quadrate, external side, natural size. Ciply (Hainault) near Mons. Upper Cretaceous (Upper Senonian); original in Brussels Museum. L. DOLLO: Bull. Soc. belg. Géol., 1904, XVIII, pl. vi, fig. 6.

Showing the tympanic operculum (*o. t.*) or thickened and calcified tympanic membrane, in adaptation to diving to great depths.


S. s.
A. t.
P
A. s.
E. c.
O. t.
A. i.
B.
S m.

[ANNALS N. Y. ACAD. SCI., Vol. XIX, No. 5, Part I, pp. 121–134. Pll. XI–XIII.
4 December, 1909.]

ON THE ORIGIN AND SEQUENCES OF THE MINERALS OF THE NEWARK (TRIASSIC) IGNEOUS ROCKS[1] OF NEW JERSEY.

BY WALLACE GOOLD LEVISON.

(*Read May 12, 1909, before the New York Mineralogical Club.*)

As early as the year 1850 most of the minerals which occur in trap rocks had been found in the trap at Bergen Hill, N. J., but evidently near the surface and not in notably fine specimens.[2] The Erie railroad tunnel, technically known as Bergen Tunnel No. 1, begun in June, 1856, bored through the ridge by the tedious method of hand drilling and blasting with black powder by August 20, 1859, and opened for traffic early in 1861,[3] first reached the deeper recesses of the New Jersey trap in this locality and so disclosed the wealth of zeolites and associated minerals which has made it famous. Bergen Tunnel No. 2,[4] and others also productive of such minerals followed, but the exigencies of tunneling opposed investigation of the conditions under which they occurred. Not until later, when high explosives, percussion machine drills, rock crushers and the rotary kiln for making cement were perfected and led to the opening of numerous and extensive quarries throughout the State for the production of broken stone to be used in the macadam and concrete industries, were the minerals of the New Jersey trap satisfactorily accessible for study *in situ*.

The visitor to a trap quarry productive of minerals finds that at every depth so far reached the trap rock is riven by splits, joints and seams, or is cellular with cavities, many of which are lined with clusters of beautiful crystals or filled solidly with minerals quite foreign to the trap in composition. Few investigations appear to have extended as yet below tide level or the water table. Conceding trap to be of igneous origin it might be

[1] N. J. Geol. Survey, Ann. Report, 1907, p. 103.

[2] See J. D. DANA, Syst. Min., 3d. ed. 1850.

[3] From private records. See also H. S. DRINKER, Tunneling Explosives and Rock Drills, N. Y., 1882, p. 1084.

[4] DRINKER: *op. cit.*, p. 1038. The Delaware Lackawanna & Western Railroad tunnel, cut between 1869 and 1874. Hand labor in heading, Ingersol drills in bottom. Rend Rock powder used in preference to dynamite.

expected that some of these minerals would be of like origin, but such is rarely the case. As a rule they are minerals which are destructible by even a moderate heat (unless perhaps under pressure),[1] and most of them contain considerable water in their composition.

Calcite, which is usually predominant among these minerals, occurring in rhombohedral, prismatic and scalenohedral crystals and in masses with rhombohedral cleavage, would be converted at a moderate heat into quicklime. Gypsum, which contains about 20% of water, would be dehydrated into plaster of Paris. Thaumasite, which occurs liberally in some of the quarries, contains both of these minerals. Pectolite, which is of very general occurrence, contains from 3% to 9% of water and would be dehydrated. Quartz, which occurs as rock crystal and chalcedony, is disintegrated when heated, probably by vapor pressure generated from liquids in microscopic cavities.

The zeolites proper, of which the crystals chiefly consist and which are the minerals more exclusively characteristic of the trap, would, as their name implies, fuse into shapeless masses. All contain water of crystallization. Many circumstances observed in the New Jersey localities seem to indicate that these minerals have been or are now being produced simply by crystallization from solution, the solvent being probably water and the dissolved material, chiefly the trap rock itself.

An average of four analyses, three by R. B. Gage[2] and one by L. C. Eakins[3] of the diabase of the Newark Formation from New Jersey localities near those productive of trap minerals, gives its composition approximately as follows:

SiO_2	53.36
Al_2O_3	13.40
Fe_2O_3	1.78
FeO	9.93
MgO	8.14
CaO	8.30
Na_2O, K_2O	3.49
TiO_2	1.35
P_2O_5	.27
MnO	.20
	100.22

[1] T. GRAHAM: Elem. Inorg. Chem. Phil., p. 181. 1858.
[2] J. V. LEWIS: N. J. State Geol. Survey Report for 1907, p. 121.
[3] F. W. CLARKE: U. S. Geol. Survey Bull. No. 228, p. 47. Basalt from the Watchung Mountain, Orange Auvergnose.

These appear to be analyses of typical trap rock, not of the special sheets and fragments which occupy the joints in the diabase, or the fragments which make up the brecciated facies, or the material of the amygdaloidal or vesicular trap which seem most productive of trap minerals. From these analyses, however, trap rock appears to contain all the constituents usually found in the common trap minerals, with the singular exception of boron, which is a principal constituent of datolite and fluorine, and of which apophyllite generally but not always contains a small proportion. Datolite is a basic orthosilicate of boron and calcium[1] which occurs liberally in some of the New Jersey quarries, sparingly or not at all in others, usually directly upon the trap.

The origin of the trap minerals, as well as many others, has long been attributed to the action of water, by some under ordinary present temperature conditions,[2] by others to magmatic water and hydrothermal processes.[3] In the New Jersey trap the frequent occurrence in cavities or parts of fissures of the remains of previously formed crystals now apparently undergoing solution and in close juxtaposition thereto of exquisitely perfect crystals both microscopic and macroscopic in beautiful groups, apparently now in process of development, seems to indicate that water under present conditions is still actively engaged in both their dissolution and their generation. Some interesting results apparently of these contending processes occur in crystals of calcite at Upper Montclair, N. J., consisting of etchings and oscillations of growth. Such a crystal is shown in Plate XI, Fig. 1.[4]

Probably both rain and spring water take part in the production of trap minerals. With reference to the solubility of New Jersey trap in meteoric water, the following experiment is of interest: A quantity of hard trap rock from a quarry at Upper Montclair, N. J., broken into pieces about 6 mm. in diameter was washed free from dust with distilled water and air-dried on filtering paper. Then 100 grammes of this broken stone was submerged in 200 cc. of distilled water in a covered glass jar. It was frequently stirred, and the water gradually became turbid with flocculi of a dark greenish color. Sixteen days later the water was poured off the trap rock, each piece of the latter washed with a jet of distilled water, the solution and wash water filtered and then evaporated at 100° C. in a platinum dish to dryness. With the same broken stone, again air dried, the experiment was repeated.

---

[1] E. S. Dana. Syst. Min., N. Y., p 504, 1892.

[2] G. Bischoff. Elem. Chem. & Phys Geol Vol. 1, pp. 57, London, 1854; 58; Vol. 2, pp. 116, 136, 137, 211. 1855; Vol 3, 1859, pp. 57, 299.

[3] See J. V. Lewis, N. J. State Geol. Survey Report for 1907, p 166.

[4] Photographed from a specimen in the collection of Mr. George E. Ashby, of New York.

Exp. 1.	The residue weighed	0.0378	gramme
Exp. 2.	" " "	0.0367	"
	Average	0.0372	"

Hence one liter of water acting for sixteen days on 500 grammes of this broken trap would dissolve 0.1860 gramme of its constituent material. The above residues were chiefly white, and dissolved almost entirely in hydrochloric acid, with slight effervescence. A small quantity of a brownish material, apparently organic matter, remained. With the spectroscope, the solution gave lines of sodium and calcium.

In the residue No. 2 above silica and alumina were determined as follows:

SiO_2	0.0052	gramme
$Al_2O_3+Fe_2O_3$	0.0023	"

Hence one liter of water acting for sixteen days on 500 grammes of the above broken trap would dissolve 0.0260 gramme of silica and 0.0115 gramme of alumina.

The greenish flocculent matter collected on the filter was dried, ignited and weighed, as follows:

Experiment 1,	0.0514	gramme
Experiment 2,	0.0936	"

Hence one liter of water acting for sixteen days on 500 grammes of the above trap would remove

Experiment 1,	0.2570	gramme
Experiment 2,	0.1680	"

This substance before ignition resembled diabantite. After ignition, it had a ferruginous orange color. A small quantity of the natural soft coating was taken from one side of a crevice in a specimen of trap, and after ignition it had a similar color.

Trap rock being thus soluble in pure water, it would probably be still more soluble in meteoric water which had absorbed carbonic acid, oxygen, organic acids or other such substances before reaching it. Rain becomes charged with gases acquired from the air in falling, taking up from 3 to 30 cc. per liter. The oxygen is found in larger proportion than in air, being sometimes as much as 38% of the dissolved gases. It also contains about 3% of carbonic acid and traces of carbonate and nitrate of ammonia and free nitric acid, besides small solid particles of dust, salts and organic matter.[1] In

[1] V. B. Lewes: Service Chemistry, p. 102, London, 1895.

volcanic districts it thus absorbs sulphurous acid and hydric sulphide; over bog lands, marsh gas; and in manufacturing districts, hydric chloride and chlorine.[1] Rain and dew spreading over growing land vegetation would seem likely to acquire considerable of the oxygen exhaled as a function of growth. The seepage and overflow of pools and streamlets in which algæ are flourishing would be highly charged with oxygen. I have collected in a few days about half a liter of oxygen, pure enough to relight a glowing taper, by simply inverting a jar over a rank growth of filamentous algæ in a self-sustaining aquarium. Any meteoric water seeping through decaying vegetation would seem likely to absorb considerable carbonic acid and perhaps crenic[2] or other organic acids and compounds, and such water previously oxygenated would seem likely to acquire a greater charge of carbonic acid by its own reaction upon such material.[3] Oxygenated water reaching the trap more directly would evidently have a reaction upon it differing from the above.

"By the continuous action of water charged with carbonic acid, even in small proportion, granite and other hard rocks are disintegrated, and the changes effected, insignificant as at first sight they may appear, in the lapse of time become of great extent and importance."[4]

To determine whether the New Jersey trap rock is more soluble in water charged with carbonic acid than in pure water, the experiment previously described was repeated, with the modification that for about an hour each morning and evening of the sixteen days, carbonic anhydride, freed from every trace of hydrochloric acid vapor, was allowed to bubble slowly through the water in which the trap was immersed. The total amount of gas generated by about 15 cc. of commercial hydrochloric acid acting on an excess of marble was the quantity usually transmitted. The residue from the 200 cc. of the solution was white and weighed 0.1226 gramme. Hence one liter of water thus partly charged with carbonic acid acting upon 500 grammes of trap from Upper Montclair, N. J., for sixteen days would dissolve 0.6130 gramme of its constituent material.

The trap solution was much less turbid than that in pure water. The material which caused its turbidity collected upon the filter contained some particles which appeared to be trap mechanically separated. These were removed and weighed 2.4 milligrammes after ignition. The remainder of the material weighed 21.4 milligrammes. The latter would correspond to 0.1070 gramme produced by the action of one liter of water containing CO_2 on 500 grammes of trap in sixteen days.

---

[1] V. B. Lewes: *op. cit.*, p. 215.
[2] G. Bischoff: Elem. Chem. & Phys. Geol., Vol. 1, p. 166. London, 1854.
[3] V. B. Lewes: *op. cit.*, p. 100.
[4] W. A. Miller: Elem. Chem., Part 2, p. 50. N. Y., 1868.

That meteoric waters charged with such other substances as those above mentioned would have a much greater solvent action than pure water upon trap rock, while probable, seems not to have been as yet experimentally established.

In either case meteoric water, penetrating the New Jersey trap from above, finds its way downward through numerous crevices and joints in the rock, even when they are only of microscopic width, dissolves the trap on both sides of, and thus gradually widens them. The more or less concentrated solution collects in natural cavities or larger crevices previously formed and there, apparently, deposits chiefly in crystals the complex materials it carries.[1]

By what process is the solution caused to deposit its contents? It seems little likely to be evaporation, but there are several other known processes which jointly or separately could possibly result in the production of these minerals from solution under the apparent conditions. For example, the water could become charged with a soluble constituent of the trap, part or all of which it might have to deposit, as in its further progress it acquired another constituent.[2] This is a known process of deposition from solution but not of common occurrence.

Another cause for the deposition of substances from solution is a change of solubility with change of temperature. Some substances are more soluble in warm, others in cold water. A change of one degree in temperature in a saturated solution could cause some deposition of its contents. Water, upon freezing, excludes all substances it may hold in solution, whether solid, liquid or gaseous. In case such a solution as that above described were frozen in a fissure in the rock, upon again becoming liquid it could drain away without redissolving the material it had deposited.

Variations of pressure, acting in most cases, inversely to variations of temperature, increase or decrease the saturation capacity of solvents.[3] Thus the solvent action of meteoric water may be increased the deeper a descending column penetrates below the surface. Upon the subsidence of such a column to a subsurface level during a dry interval, or upon the escape of such water as spring water with consequent release of pressure, this condition is reversed and perhaps a deposition of dissolved material may occur.

The principle of diffusion also may be involved in the sorting out of the dissolved substances and their deposition to form these minerals.[4] It seems

[1] According to Bischoff (Chem. & Phys. Geol. V. 2; London 1859 pp. 116 & 137) analcite and natrolite are the only zeolites which do not contain silicate of lime and the only ones that could have been produced from water containing CO_2.

[2] W. A. Miller. Elem. Inorg. Chem., Part 1, Chem. Phys. p. 63, N. Y., 1864.

[3] J. P. Iddings: Igneous Rocks, Vol. I, p. 158, New York, 1909.

[4] *Id.*, p. 70.

likely, however, that their production is chiefly due to chemical reactions resulting in the formation of less, from more soluble substances in solution.

Several crystallized minerals, including some zeolites, have been artificially produced from aqueous solution, both accidentally and intentionally.[1]

That water percolating from above is concerned in the production of the New Jersey trap minerals appears to be indicated by the circumstance that crystals which occur on the upper sides of cavities are usually unimpaired, even though colored, while those which occur on the under sides have usually occluded a sedimentary material resembling yellow or red oxide of iron or a ferruginous clay in fine particles, which also frequently covers them with a coating evidently imbedded in the surface and impossible to remove. Clusters of crystals projecting from the sides of cavities are frequently thus coated on the upper, while unsullied on the under surfaces, a circumstance of common occurrence with calcite and prehnite. The lustrous undersurface of such an occurrence of reniform prehnite is shown in Plate XI, Fig. 2. The material of this coating, which is also often occluded throughout a crystal, consists perhaps of the 2% to 3% of ferric iron with other undissolved residues of the trap and some clay from the top soil all carried down mechanically by the water. It sometimes has a bright red color as though chiefly a ferric compound, thus occurring on crystallized quartz and heulandite at West Paterson and stilbite and heulandite at Upper Montclair, common, and on heulandite at Great Notch, rare.

Spring water would act upon the trap somewhat differently from rain water for several reasons, and coming perhaps through various other rocks before entering the trap may so acquire the boric acid and fluorine required and be accountable for the production of datolite, which occurs liberally in some quarries and contains the large proportion of 21% of boric acid; and also such apophyllite as contains fluorine.

Release of pressure may account for the deposition by spring waters of such crystallized minerals in the trap, as it does for the escape of gases and the deposition of sulphur from sulphur waters, iron carbonate and oxides from chalybeate waters, and calcareous and siliceous sinters from hot-spring waters.

The microscopic crevices through which the water enters cavities in the rock are often disclosed at Great Notch, N. J., by the sledge hammer. Large yellow calcite crystals somewhat resembling those of Joplin, Mo., occur there in such cavities, but any attempt to trim the rock away around such a crystal usually results in its splitting directly through the cavity and the destruction of the crystal. The parted sides of the split are often covered

[1] J. P. Iddings: *op. cit.*, p. 96.

with a thin dark colored film and show that the split followed a seam which was almost imperceptible before it was thus disclosed.[1]

To study the conditions existing in a crevice or cavity containing minerals previously undisturbed, it is necessary for the investigator to be present when it is first exposed directly after a blast. Although I have spent many days in quarries, I have been favored with few such opportunities, perhaps a dozen in all, and have invariably found the contents of the cavity saturated with moisture. In some cases the crevice or cavity was filled with a viscid material resembling paste in appearance and covering clusters of superior crystals.[2] I have seen cavities of various sizes, partly or entirely filled with water and often containing no mineral deposit whatever, exposed by the sledge hammer in apparently solid trap.

Probably the water reaches such cavities through microscopic crevices although Bischoff[3] credits it with penetrating through the pores of the rock. Occasionally a cavity is filled with material resembling wet snow, covering groups of crystals, sometimes on a lining of pectolite. This material is sometimes thaumasite penetrated by concretions and needles of pectolite, sometimes apparently laumontite, in microscopic crystals. In some cases a narrow crevice will be lined on opposite sides with two different minerals as heulandite and calcite, almost in contact, but each free from the other. In other cases the crevice will be filled solid, where it is narrow, with a single mineral, and where it is wider this divides into linings with finely crystallized faces.

The deposition of two or three of the trap minerals synchronously or in close alternation produces occasional cryptocrystalline masses attractive in appearance, but having the composition and structure of a rock rather than a mineral. Such would be a solid mass composed of needles of pectolite or natrolite carrying parasitic crystals of apophyllite, gmelinite or calcite as illustrated in Plate XI, Figs. 3 and 4, and Plate XII, Figs. 1 and 2. Sometimes, as in Plate XI, Fig. 3, the parasitic mineral is distinguishable throughout the resulting solid, but usually the mass appears, deceptively, to consist only of the predominant mineral, while it approximates a solid solution in character, as is the case with much of the pectolite from Woodcliff, N. J. (Plate XIII, Fig. 3) in which many of the needles are invested with microscopic crystals of calcite. To this may perhaps be attributed the exceptionally strong yellow fluorescence and tribophosphorescence of the Woodcliff and some other pectelites, as the thermo- and tribophosphor-

[1] See G. Bischoff, *op. cit.*, Vol. 1, p. 10.

[2] A gelatinous substance having the composition of chabazite has been noted between calcite crystals by Renevier. E. S. Dana, Syst. Min., p. 590. N. Y., 1892.

[3] *Op. cit.* Vol. 1, p. 54.

escence of certain tremolites have been attributed to a somewhat similar inclusion of dolomite.[1]

In several localities a mineral occurs in flexible filaments sometimes as fine as hair.[2] One or more of these, perhaps two centimeters in length, may project from a face of a crystal of datolite or calcite, or they may be attached in clusters directly to the trap or to a film of diabantite upon the trap as in the example from Snake Hill illustrated in Plate XII, Fig. 3. Often they cross a cavity between adjacent groups of datolite crystals intersecting in all directions. Each filament frequently supports a series of crystals of calcite, datolite, apophyllite or other minerals like beads upon a thread or dew drops on a spider's web, ranging in size from microscopic to macroscopic and with all faces complete.

A large quantity of such a filamentary mineral was recently found by Mr. James G. Manchester, of New York, thus associated with datolite in a nearly vertical crevice in the Erie Railroad cut through Bergen Hill. In part it was massed together resembling asbestos, in part disposed as above described (Plate XII, Fig. 4). Throughout it was invested with crystals of various sizes and kinds, a large quantity of which, chiefly datolite, fell from the cavity like sand when it was disturbed. Many of these were euhedral and probably had been supported on the filaments.[3] The matted filaments, when mounted in balsam, were found to entangle a multitude of microscopic crystals of several minerals easily distinguishable from each other in polarized light. At Great Notch a similar filamentary mineral has been noted (but rarely) forming fringes on microscopic plates of a black mineral.

Commonly all these minerals are separated from the trap by a thin film of a material varying from gray to greenish black in color and often having the feel of talc (Plate XII, Figs. 2 and 3). Apparently similar material of a greenish black color occasionally fills small crevices in the trap and in many cases occurs in large quantity, as at Woodcliff (Guttenberg) where, together with prehnite invested with beautiful microscopic crystals of other trap minerals and numerous large crystals of such minerals, it occupies the interstices between fragments and sheets of partly decomposed trap that fill a nearly vertical fault or shear zone about a meter wide in the Palisade

[1] BOURNON, quoted by PARKER CLEVELAND. Elem. Treatise on Mineralogy and Geology, p. 323. Boston, 1816

[2] This is probably a fibrous natrolite which according to Mr. F A. Canfield was called fibrolated-natrolite by Dr. A. E Foote. This name is however not mentioned in Dana, Syst. Min., New York, 1892 Fine specimens from Bergen Tunnel No. 2 are in the collection of Mr. Canfield at Dover, N J.

[3] Since this paper was presented, these datolite crystals have been described by W. E. Ford and J. L. Pogue, Am. Jour. Sci., IV, xxviii, p. 187, Aug., 1909.

diabase.[1] This material appears to be the so called diabantite[2] and simply an insoluble residue of trap otherwise dissolved in water.

Dr. Alexis A. Julien in a recent discussion of the composition of minerals[3] has suggested that diabantite is not a mineral but a mixture of minerals which as deduced from analyses by G. W. Hawes of the trap at Farmington, Conn., are as follows: pyroxene (residual), enstatite (residual), prochlorite, ekmanite, deweylite, limonite, periclase. He considers the first two of these to be residues from the solution of the trap and the remainder recombinations of its dissolved constituents.

According to Dana[4] diabantite is apparently a product of the alteration of the augite of the diabase; according to Emerson, the first product of the decomposition of the diabase[5] "and seems to have been formed by slow deposition from water."[6]

In each quarry the minerals have usually a prevailing characteristic color, ranging from pure white in some quarries to yellowish white, greenish white, yellow, orange, red and brown in others. This seems due to the iron in the trap, chiefly perhaps to its liberal content of ferrous iron. As a quarry is extended, however, rock of a different facies may be encountered, and in course of time the preponderant species of minerals and their prevailing color are liable to change.

Although Bischoff[7] and subsequently others have recorded many details of this kind relating to the occurrence of minerals in general it seemed to me that a record of some of those observed in the New Jersey trap quarries may help eventually to disclose the genesis of the zeolitic group. Among such details the order of generation of the species seems important and following is a list of such sequences in their occurrence as I have noted them in New Jersey localities, arranged alphabetically.

Sequence or order of occurrence of the minerals.

Albite.[8] Sequent on calcite, chabazite, diabantite and quartz, West Paterson.

[1] J. V. Lewis: Geol. Survey of N. J., Annual Report for 1907, p. 107.
[2] *Id.*, p. 152.
[3] Annals N. Y. Acad. Sci. XVIII, 139–142. 1908.
[4] Syst. Min., 659–660. 1892.
[5] Am. Jour. Sci. III, XXIV, 198–201.
[6] U. S. Geol. Survey, Bull., No. 126, pp. 72–74.
[7] Chem. and Phys. Geol., German edition 1847; 1848 et seq., English (Cavendish Soc.) edition, London, Vol. 1, 1854, Vol. 2, 1855, Vol. 3, 1859.
[8] Identified by Dr. C. Palache according to Mr. F. A. Canfield.

Analcite. Sequent on trap, Shadyside;[1] on pink and white apophyllite, Snake Hill;[2] on calcite, Shadyside, West Paterson and Erie Cut;[3] on datolite, Erie Cut; on gmelinite, Snake Hill;[4] on white and red heulandite, West Paterson; on natrolite and terminated pectolite, Snake Hill.

Apophyllite. Sequent on trap, many localities; on analcite, Erie cut, (Pl. XIII, Fig. 1) on calcite, West Paterson, Shadyside and Snake Hill; on datolite, Erie cut (common) and Snake Hill; on diabantite, Shadyside; on laumontite, Snake Hill and Great Notch; on natrolite, Snake Hill; on pectolite, in microscopic crystals (Plate XI, Fig. 3) and large crystals, Snake Hill; in large crystals, Hoxie's quarry, Paterson, and Berger's quarry, West Paterson; on prehnite Woodcliff;[5] on quartz crystals, Hoxie's quarry, Paterson; on quartz pseudomorph, Great Notch; on stilbite, Shadyside.

Calcite. Sequent on calcite, one habit on another, Erie cut;[6] on chabazite, West Paterson; on datolite, in large rhombohedrons, Erie cut and Snake Hill; on diabantite in rhombohedrons, Shadyside, in scalenohedrons, Woodcliff; on heulandite, West Paterson; on natrolite, Great Notch (Plate XII, Fig. 1) and Woodcliff (Plate XII, Fig. 2); on pectolite, Woodcliff and West Paterson; on prehnite in scalenohedrons, Great Notch, and Woodcliff (Plate XII, Fig. 2) on quartz (rock crystal, amethyst, chalcedony or pseudomorphous), Great Notch, West Paterson and Snake Hill; on stilbite in scalenohedrons, Upper Montclair (Plate XIII, Fig. 2); impaled on flexible filaments of an unidentified mineral in rhombohedrons, Snake Hill (Plate XII, Fig. 3).

Chabazite. Sequent on calcite, West Paterson; on datolite, West Paterson; on quartz, West Paterson and Great Notch; on stilbite, West Paterson.

Chalcopyrite. Sequent on calcite, Erie cut, Snake Hill and Homestead;[7] on datolite, Erie cut.

Datolite. Sequent on apophyllite, Erie cut; on gmelinite and pectolite, West Paterson; on a filamentary mineral Erie cut (Plate XII, Fig. 4) and Snake Hill.

---

[1] Shadyside. The Hudson River terminal of the N. Y. Susquehanna and Western R. R. tunnel.

[2] Snake Hill. The Penitentiary Quarry is to be understood unless others are mentioned.

[3] Erie Cut herein signifies the new open cut now in process of construction (1909) through Bergen Hill by the Erie Railroad.

[4] And Pinnacle Island, Nova Scotia.

[5] Woodcliff is a small settlement on the Palisades where part of the cliff was removed. It is a section of Guttenberg.

[6] H. P. Whitlock; N. Y. State Museum, fifth report of the director, p. 219. 1908.

[7] Homestead is the western terminal of the new Pennsylvania R. R. tunnels through Bergen Hill to Manhattan Borough, New York.

Diabantite ? Sequent on datolite and gmelinite, Snake Hill.

Epidote. Sequent on quartz (rare), Great Notch.

Galena. Sequent on calcite, Homestead.

Gmelinite. Sequent on calcite, datolite, heulandite and pectolite, Snake Hill (Plate XI, Fig. 4).

Hematite. Transparent sequent on calcite and laumontite, ordinary on white and amethystine quartz, West Paterson.

Heulandite. Sequent on calcite, West Paterson; on datolite, West Paterson and Snake Hill; on gmelinite, West Paterson; on pectolite, Hoxie's quarry, Paterson, and West Paterson; on quartz, pseudomorphous, Hoxie's quarry, Paterson; on quartz, crystallized, white and amethystine, West Paterson.

Laumontite. Sequent on apophyllite, Snake Hill; on calcite, Great Notch; on datolite, Snake Hill; on gmelinite, Snake Hill; on heulandite, Hoxie's quarry, Paterson, and Great Notch; on natrolite, Great Notch.

Natrolite. Sequent on apophyllite, Snake Hill and Erie cut; on calcite, Snake Hill and Woodcliff; on datolite, Snake Hill and Erie cut; on diabantite, Shadyside and Woodcliff (Plate XII, Fig. 2); on pectolite, Snake Hill; ordinary and with fibrous terminations, on prehnite, Woodcliff and Bergen tunnel No. 2; fibrous on trap, Bergen tunnel No. 2.[1]

Pectolite. Sequent on calcite, Hoxie's quarry (rare); and Woodcliff; on prehnite, Woodcliff (Plate XIII, Fig. 3); on quartz (pseudomorphous), West Paterson; on quartz (chalcedony), Hoxie's quarry, Paterson; on thaumasite, West Paterson and Great Notch.

Prehnite. Sequent on datolite, in crystals and globular, West Paterson, incrusting large crystals of datolite, Hoxie's quarry, Paterson; on diabantite, Woodcliff; on pectolite and also pseudomorphous after a radiated mineral probably pectolite, West Paterson; on pectolite, Upper Montclair; on quartz crystals, in separate microscopic crystals (rare) in hemispherical forms and in incrustations with and without datolite (common), Great Notch; on scolecite, West Paterson.

Pyrite. Sequent on analcite, Snake Hill (rare) and Erie cut (Plate XIII, Fig. 1); on apophyllite, in brilliant microscopic crystals, Snake Hill (common), and Erie cut (Plate XIII, Fig. 1); on calcite, in microscopic cubes Shadyside; on plates and scalenohedrons, private quarry, Snake Hill; on rhombohedral crystals, Erie cut; on datolite in microscopic cubes, Snake Hill and Erie cut; on diabantite, in various forms, Shadyside; on heulandite, microscopic in cubes (common), in square prisms several diameters in length and in rectangular plates (rare), Shadyside (Plate XIII, Fig. 4); on

[1] In the collection of Mr. F. A. Canfield, Dover, N. J.

stilbite, in microscopic crystals, Snake Hill Shadyside, and Erie cut (common).

Quartz, 1. *Rock Crystal.* Sequent on chabazite, West Paterson; on pseudomorphous quartz, Upper Montclair, Great Notch, West Paterson and Hoxie's quarry, Paterson;

2. *Amethyst.* Sequent on pseudomorphous quartz, Hoxie's quarry, Paterson, and West Paterson;

3. *Chalcedony.* Sequent, usually on the trap, several quarries.

Scolecite. Sequent on prehnite, West Paterson.

Selenite. Sequent on trap, Great Notch and West Paterson.

Stilbite. Sequent on apophyllite, Snake Hill, common (the reverse rare); on calcite in microscopic crystals, private quarry, Snake Hill, and Erie cut, common; in large clusters, West Paterson and Upper Montclair; on datolite in microscopic crystals, Snake Hill and Erie cut; on heulandite, Millington and West Paterson; on quartz, crystallized, Great Notch and West Paterson; on pseudomorphous quartz, Upper Montclair (common).

Thaumasite. Sequent on heulandite, West Paterson; on pectolite, West Paterson and Great Notch; on stilbite, West Paterson.

Unidentified mineral in filaments. Sequent on trap and diabantite, Snake Hill (Plate XII, Fig. 3), Erie cut and Woodcliff; on calcite and datolite, Erie cut (Plate XII, Fig. 4) and Snake Hill.

Summary of Sequences.

1. Trap, datolite, apophyllite, pyrite, analcite; not common. Snake Hill and Erie cut (best specimen).
2. Trap, datolite, heulandite, gmelinite. West Paterson.
3. Trap, datolite, gmelinite, laumontite. Snake Hill.
4. Trap, calcite, drusy quartz, heulandite. West Paterson.
5. Trap, calcite, quartz (crystallized), datolite, prehnite in balls. Great Notch.
6. Trap, calcite, quartz (crystallized), prehnite in microscopic crystals. Great Notch.
7. Trap, pectolite, natrolite, analcite. Snake Hill.
8. Trap, stilbite, calcite, quartz (pseudomorphous), stilbite. Upper Montclair.

Conclusions.

The quantitative estimates of the solubility of trap above given apply only to the material employed. Determinations of the solubility of various other

samples would obviously be necessary to serve as a basis for general conclusions.

As regards sequences these notes seem to indicate no conspicuously prevalent order in the genesis of the New Jersey trap minerals.

Quartz, calcite and datolite appear to be, in the order named, most generally deposited first upon the trap. One or another of these three minerals usually thus prevails in a given quarry or part of a quarry at a given time; but in the same quarry at a later time, when a different texture of rock is in process of excavation, another of them may be the prevalent mineral thus deposited. Likewise, in two adjacent quarries or even parts of the same quarry the prevalent minerals differ considerably. Thus, datolite has been plentiful in one of the two adjacent quarries at Snake Hill and seldom found in the other. Again, in one of two adjacent quarries at Great Notch datolite in opaque crystals and prehnite in spheroids, both on crystallized quartz, were extremely prevalent and almost no thaumasite occurred. In the other quarry, now being actively worked, thaumasite is abundant and the above-mentioned combination rare or absent. In fact, the prevalent minerals often differ greatly as new mineral-producing rock areas but a few yards distant are reached.

The minerals sequent upon datolite, calcite and quartz seem to be more numerous in the order named. Of the species which are more plentiful, apophyllite appears to occur upon the larger number of other species. Calcic sulphate not of frequent occurrence in the ordinary form of selenite is plentiful as a constituent of thaumasite. Conclusions in regard to sequences must, however, be only tentative until records of other localities are available for reference.

PLATE XI

Fig. 1. CALCITE, Upper Montclair, N. J. Natural size. From the collection of Mr. George E. Ashby of N. Y.

The faces of the interior crystal are comparatively smooth but are formed only of a thin film perforated with minute holes within which it consists chiefly of thin parallel plates with intervening spaces partly filled with a loose dark colored powder which may be washed out leaving them vacant. Surrounding this interior crystal is a much less corroded envelope with terminations in fair condition. The specimen was found as shown in the illustration with both envelopes partly removed, disclosing its internal structure. The small projection on the left is stilbite to which it was attached (compare Plate XIII, Fig. 2.)

Fig. 2. PREHNITE, Hoxie's Quarry, Paterson, N. J.

A specimen which projected from the side of a cavity. The side shown was the under side and is unsullied. The opposite side is sullied with a coating of sediment partly included. Collected June 23, 1892.

Fig. 3. APOPHYLLITE parasitic on PECTOLITE, Snake Hill, N. J.

Photomicrograph. Magnified 4 diameters. Both minerals apparently are in process of deposition. The resulting solid mass resembles pectolite, but consists largely of included apophyllite discernible all through it. Collected May 30, 1899.

Fig. 4. GMELINITE, CALCITE and other minerals.

These are supported on and between acicular crystals of pectolite apparently in process of deposition, thus resulting in a solid mass resembling pectolite but including all these minerals. Photomicrograph Magnified 4 diameters. Collected May 30, 1899.


1
2
3
4

PLATE XII.

Fig. 1. Scalenohedrons of CALCITE parasitic on crystals of NATROLITE.

From the exterior of a spheroidal aggregation solid within. A specimen from Great Notch, N. J., in the collection of Mr. James G. Manchester, of New York. Photomicrograph. Enlarged 4¾ diameters. The resulting solid resembles massive natrolite, but evidently contains much calcite, thus inclosed. Collected in July, 1909.

Fig. 2. NATROLITE and PREHNITE supporting sequent CALCITE.

The resulting solid natrolite will consist largely of inclosed calcite. Collected Nov. 16, 1895.

Fig. 3. A filamentary mineral on a thin coating of DIABANTITE on trap and supporting parasitic crystals of various minerals. Snake Hill, N. J.

The larger and more conspicuous of these are rhombohedrons of calcite. Photomicrograph. Magnified 3½ diameters.

Fig. 4. A filamentary mineral in a cavity between crystals of DATOLITE and CALCITE. Erie Cut, Bergen Hill, N. J. Photomicrograph. Magnified 3½ diameters.

The filaments support parasitic crystals of various minerals, the larger and more numerous of which are datolite. Collected February 27, 1909.

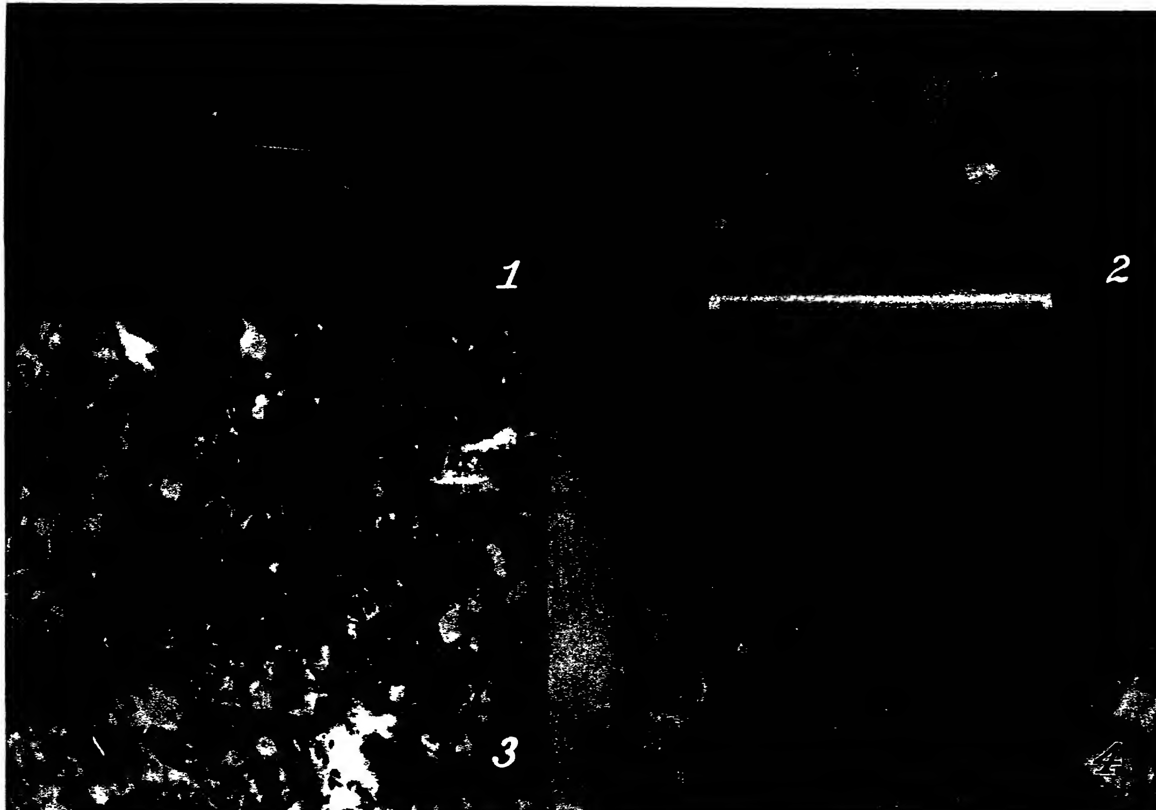

1
2
3
4

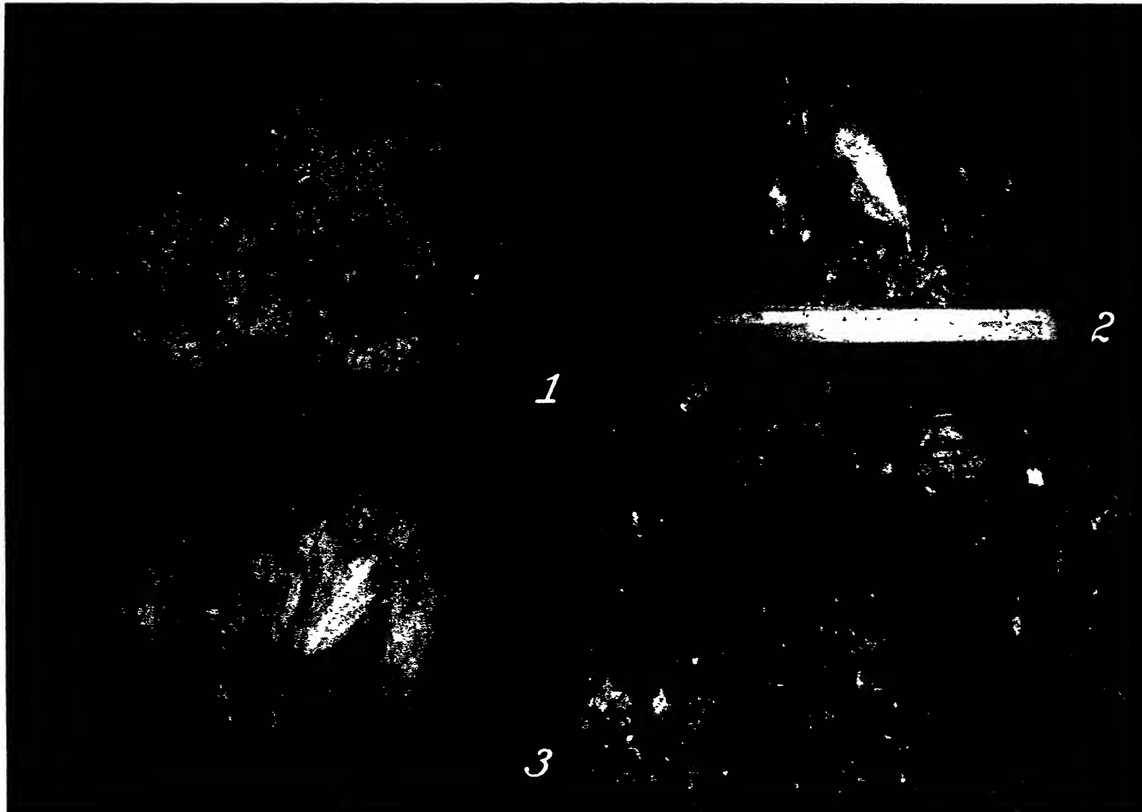
PLATE XIII.

Fig. 1. APOPHYLLITE and ANALCITE on DATOLITE. Erie Cut, Bergen Hill, N. J. The apophyllite crystals in some cases appear to be sequent upon the analcite and certain of their faces are besprinkled with minute cubic crystals of pyrite, too small to be visible in the illustration. In a few cases similar sporadic cubes of pyrite occur on the analcite. Collected February 27, 1909.

Fig. 2. CALCITE sequent on STILBITE. Upper Montclair, N. J. The calcite crystals here commonly include stilbite, and stilbite is frequently sequent on the calcite. Collected, April 24, 1894.

Fig. 3. PECTOLITE sequent upon a plate of PREHNITE. Woodcliff, N. J. Collected April 23, 1896.

Fig. 4. PYRITE in prisms and cubes on HEULANDITE. Shadyside, N. J. Photomicrograph. Magnified 3½ diameters. Collected August 5, 1893.


1
2
3

[ANNALS N. Y. ACAD. SCI., Vol. XIX, No. 6, Part I, pp. 135–147. 27 December, 1909.]

THE GUADALUPIAN FAUNA AND NEW STRATIGRAPHIC EVIDENCE.[1]

BY GEORGE H. GIRTY.

When the Guadalupian fauna was described its stratigraphic relations were unknown, except with formations in the immediate vicinity. Even these were known chiefly to the south and west. In spite of this lack of stratigraphic data I felt compelled to consider in a tentative manner the relations of the Guadalupian fauna with the faunas of the Mississippi Valley, not only biologically but in the category of geologic sequence;[2] failure to do so would surely have been a source of criticism. The importance of the fauna and its affinities with those of Europe and Asia made it hardly possible to avoid this point, while the incompleteness of the data made it necessary to engage it with extreme caution. The evidence employed had, in the nature of the case, to be paleontological.

One of the pivotal facts in the evidence, regarding which there can hardly be a difference of opinion, is that the Guadalupian fauna is within certain limits quite different from any faunas of the Mississippi Valley. Two interpretations could be given to this fact. Either it was due to environment and the Guadalupian fauna was equivalent to some very different fauna in the Mississippi Valley, or it was due to time, and the Guadalupian fauna belonged to a horizon not represented by the faunas of that area. One explanation or the other it was necessary to adopt as a working hypothesis. The premise upon which the science of stratigraphic paleontology proceeds is, as is well known, that two horizons containing the same fauna should not be regarded as different, or two horizons containing different faunas should not be regarded as the same, unless substantial stratigraphic

[1] Published by permission of the Director of the U. S. Geological Survey.
Read by title before the New York Academy of Sciences, 6 December, 1909.

[2] In his generous critique of my Guadalupian report Dr. J. W. Beede says, "It is very difficult to determine what Dr. Girty's conclusion as to the relative age of the Guadalupian, Russian and Kansan deposits is" (Jour. Geol., vol. 17, p. 679. 1909). Dr. Beede seems to confuse my recognition that the opinion which I entertained on this point was not substantiated by conclusive evidence, and my feeling that it was necessary to discuss other hypotheses, with not having or not expressing any clearly defined opinion or hypothesis at all. The conclusion tentatively adopted was that outlined in the present paper and pretty clearly intimated on pp. 42 and 50 of the Guadalupian report.

evidence shows the facts to be otherwise. It was, therefore, the conservative course to assume that the very great difference between the Guadalupian faunas and those of the Mississippi Valley was due to time rather than to environment. The one fact then known which was unfavorable to this hypothesis was the apparently very limited distribution of the fauna, which, in the typical area, occupied nearly 4,000 feet of strata. At one time or another I have examined Carboniferous collections representing very many different horizons and scatteringly representing most of the areas in North America where Carboniferous rocks are known. If the strikingly individual facies of the Guadalupian fauna was not due to environment, why, I asked myself, did it not occur in other areas. The thickness of the series would diminish the chance of existence without discovery and the characteristic aspect of the fauna would diminish the chance of discovery without recognition. To these questions it was possible to answer that certain scanty faunas in California did show some of the notable features of the Guadalupian facies and it was also suggested that aside from such factors as non-deposition and erosion the apparent absence of this horizon might be accounted for by its representation elsewhere by non-fossiliferous strata, such as the "Red Beds" for the most part are.

Now, if the difference of facies from the more eastern faunas was due to time, it seemed probable that the Guadalupian fauna was younger rather than older than the faunas of which we have knowledge in the Mississippi Valley. This seemed to be indicated by certain intrinsic features, such as the degenerated condition of certain brachiopods, as well as by the obvious relationship with certain Asiatic and European faunas, whose position was recognized as high up in the Carboniferous section. Confirmatory evidence was also found in a fauna beneath the Guadalupian, occupying some 5,000 feet of rocks, which has a facies markedly different from the Guadalupian fauna and very much more in agreement with the familiar faunas of Kansas and the Upper Mississippi Valley. By reasoning such as this, the conclusion was suggested that the Guadalupian fauna was younger than any of the Pennsylvanian or "Permian" faunas of the Mississippi Valley.

It has already been remarked that the Guadalupian fauna, while totally different from almost anything else known in the United States, or even in the western hemisphere, yet showed certain Asiatic and European affinities. The fauna of the underlying Hueco limestone, while more comparable to the Pennsylvanian faunas of the Mississippi Valley than are those of the Guadalupian series (Capitan and Delaware Mountain formations), is rather Russian than American in its facies. It shows marked resemblance to the Gschelian fauna of the Russian section. The Gschelian lies beneath the Artinskian and Permian of Russia, just as the Hueconian lies beneath the

Delaware Mountain formation and the Capitan limestone of the trans-Pecos section. Although the faunal relation between the Delaware Mountain and Capitan faunas on the one hand and the Artinskian and Permian faunas on the other was by no means as close as between the Hueconian and Gschelian, it seemed justified to correlate in a tentative manner the two American horizons with the two Russian ones, which appear to occupy the same position in the section. Carried to a logical conclusion, it is apparent that these comparisons, if correct, would place the entire invertebrate-bearing Carboniferous section of Kansas — Pennsylvanian and Permian as well — below not only the Russian Permian, but even the Artinskian, and align it with the Gschelian and underlying beds.

While these correlations seemed measurably supported, or at least not contradicted by the evidence in hand, it was fully appreciated that the relations suggested were on trial and must be verified by more complete data before they could be accepted. It was clearly appreciated also that the fundamental proposition from which these correlations proceeded — those with the Mississippi Valley at least — that the peculiarities of the Guadalupian fauna were due to time not to environment, must be decided by further explorations. The most promising field for this purpose was toward the north, for in this direction, as represented on the imperfect maps of the region, the Guadalupe Mountains, from whose southern point the rich and interesting faunas were obtained, in their northward extension merge with the Sacramento Mountains, the western face of which swings westward until it reaches a point nearly north of El Paso. From the more northern extension of these Mountains we have had fossil evidence for many years, the faunas, however, presenting a facies very unlike the Guadalupian. The question as to what becomes of the Guadalupian rocks and faunas in the northward extension of the mountain mass whose southern end is composed of them was discussed many times with Mr. Bailey Willis and Mr. G. B. Richardson with whom I have had the pleasure of being associated in much of my work in the trans-Pecos region. Although several trips have been made to that area during the past five or six years, it has always been for a specific purpose and with a limited allotment and it seemed, to me at all events, that when the exploration in question was taken up, it should be made thorough and should be reasonably unhampered by considerations of time and expense.

In the meantime the evidence represented by our scattered and uncorrelated data in the Sacramento Mountains was accounted for by the hypothesis of erosion and deformation, for, if it seemed probable that the faunal differences of the Guadalupian from the Kansas section were not the result of environment, it was *a fortiori* improbable that corresponding differences

should be interpreted in that way with faunas so much nearer geographically. I myself was expecting an east-west fault which would put the northern area out of relationship with the southern, or a southward dip which would bring only the lower beds to view in the north.

This summer, however, while I was detained in Idaho, Mr. Richardson was able to make a hurried trip into what we had considered the critical area and with results important in their bearing on the problems in question. His facts will perhaps make it necessary to dismiss the hypothesis from which the relations of the Guadalupian to the Kansas section were tentatively considered and to conclude that the remarkable facies of the Guadalupian fauna is to a large extent, if not wholly, the result of environmental causes.

The chief facts of immediate importance, which Mr. Richardson has kindly permitted me to summarize on this occasion, but which he will present in full in another place, are these: The Guadalupian formations in passing northward from Guadalupe Point are not interrupted by east-west faults and the prevailing dip is eastward. In its northward extension the massive Capitan limestone merges along the strike into thin-bedded limestone and sandstone, the limestone element finally disappearing altogether or being represented only by thin local beds. Still farther to the north, the strata take on a red color and become part of the "Red Beds" series. Northward from Guadalupe Point fossiliferous horizons become rare in the Capitan and the collections which Mr. Richardson brought in tend to show that with the change in lithology the fauna also changes character, so that practically nothing of the typical Guadalupian facies is left. This feature I shall refer to more in detail below.

The fossiliferous limestone capping the Sacramento Mountains on their western rim and exposed at Cloudcroft northeast of Alamogordo, New Mexico, has been known to me for a good many years. The first collections were made by Mr. R. T. Hill in 1900. I visited the locality two years afterward and collections have been brought in subsequently by other members of the Survey. The presence of faulting renders it difficult to measure the section from Cloudcroft to the valley below, but the limestone at Cloudcroft is underlain by perhaps 3,000 feet of "Red Beds" and 1,500 feet of shales, sandstones and limestones, all of upper Carboniferous age. The limestone at Cloudcroft I have been tentatively correlating with the upper part of the Hueco limestone of western Texas because of certain faunal resemblances with a collection made at the Corundas Mountains, the horizon of which is in the upper part of the Hueco. The Hueco in the typical area consists of limestone throughout, even shale beds being usually wanting, and the approximate thickness is 5,000 feet. Inferentially, there-

fore, a large part of the Hueco is represented by "Red Beds" in the Cloudcroft section, appearing to be what Mr. Richardson has found the Capitan to be, a great lens in the "Red Beds" fingering toward the north into beds of clastic material, either red themselves or passing into the typical "Red Beds."

From Cloudcroft eastward the geologic structure is, according to Mr. Richardson, a regular one, with gentle eastward dips, the general trend of the surface also being toward the east but with a descent slightly less rapid than the dip of the rocks. A similar regularity and simplicity characterizes the structure southward also and it is consequently possible to determine in a general way the stratigraphic relations to the Guadalupian section of the collections made by Mr. Hill and Mr. Fisher, relations which were not previously known.

A summary of the paleontologic data contained in these collections will be of interest at this point. The identifications are preliminary to a careful discussion of the paleontology of the region, but they will serve to show the general character of the faunas. The following is a composite list from Cloudcroft, New Mexico, based upon collections made by Mr. Hill, Mr. C. A. Fisher, Mr. Richardson and myself, only the more common and significant species being included in it:

Echinocrinus sp.
Chonetes aff. *Geinitzianus*
Productus Ivesi
Productus Leei?
Productus Mexicanus?
Productus subhorridus?
Marginifera Manzanica
Marginifera Cristobalensis
Composita Mexicana
Cardiomorpha? sp.
Nucula levatiformis
Manzanella elliptica?
Aviculipecten aff. *Vanvleeti*
Myalina aff. *perniformis*
Allerisma Gilberti?
Schizodus Wheeleri?
Schizodus n. sp.
Cleidophorus aff. *Pallasi*
Bakewellia? sp.
Plagioglypta canna
Bellerophon majusculus
Euphemus subpapillosus
Bucanopsis modesta
Murchisonia terebra?
Murchisonia sp.

Euomphalus n. sp.
Naticopsis deformis
Coloceras globulare?
Domatoceras Highlandense?
Metacoceras aff. *inconspicuum*
Anisopyge inornata

This fauna is characterized to some extent by the scarcity of brachiopods and the dominance of true mollusca. The brachiopods, though reduced in variety, are apt to be extremely abundant; especially is this true of the Producti, and to a less extent of Chonetes and Composita. Nautiloids are also unusually abundant, suggesting in some respects the Nautiloid fauna of the Texas "Permian," though presumably the horizon is different. A resemblance especially close is shown to the Manzano fauna of the Rio Grande Valley in New Mexico. The facies is distinctly unlike the Pennsylvanian or "Permian" faunas of the interior basin.

About the same facies is shown by collections made at a somewhat higher horizon near Pine Spring, New Mexico. Still higher, from localities in the general vicinity of Mayhill, Ruidosa and Weed, on the eastern slope of the Sacramento Mountains, we have the following species from eight localities:

Echinocrinus sp.
Chonetes aff. *Geinitzianus*
Productus Ivesi
Productus Mexicanus?
Productus subhorridus?
Productus aff. *Irginæ*
Pugnax Osagensis var. *pusilla*
Composita Mexicana
Composita subtilita
Nucula levatiformis
Aviculipecten sp. (same at Cloudcroft)
Myalina aff. *meliniformis*
Bakewellia? sp.
Plagioglypta canna
Bellerophon sp.
Euomphalus n. sp.
Tainoceras sp.
Griffithides sp.

Not far above this general horizon, Mr. Richardson thinks, would pass the plane which farther south, where the lithologic distinctions are more sharp, divides the Hueco limestone from the Guadalupian, and several collections from the north end of the Guadalupe Mountains at Lower Penasco and Pretty Bird Creek, can, with considerable probability, be assigned to undetermined horizons in the Guadalupian. A composite list of six collections showing the most important species is as follows:

Lophophyllum? sp.
Echinocrinus sp.
Meekella striaticostata
Chonetes aff. *Geinitzianus* var.
Productus Ivesi
Productus subhorridus?
Productus Mexicanus?
Pugnax Osagensis?
Composita Mexicana
Cardiomorpha? sp.
Nucula sp.
Manzanella elliptica?
Bakewellia? sp.
Murchisonia terebra?
Bellerophon majusculus?
Euomphalus n. sp.
Naticopsis deformis?
Nautilus sp.

Here again we find the same general facies which was first noted at Cloudcroft. About 30 miles west of Roswell on the Lincoln Road, Mr. Richardson obtained a few fossils which I have identified as *Productus Leei*?, *Productus subhorridus*?, *Productus Mexicanus*? and *Composita*? sp. The stratigraphic horizon of the last is considerably higher than the preceding and occurs in beds which are apparently the continuation of the upper strata in the Guadalupe Mountains. Insofar as it goes this fauna presents the same facies as those of lower horizon farther west. Now, it is possible that among the varied Producti grouped under *P. Mexicanus*? and *P. subhorridus*? there may be some which might be identified as *P. occidentalis* of the Capitan limestone (*P. Mexicanus* itself was first described from the Capitan) or *P. Popei* of the dark limestone or *P. Texanus* of the Delaware Mountain formation, but it is apparent that the Guadalupian fauna in a characteristic form is not indicated by our collections in the northward extension of the Guadalupian rocks, all the variety, all the peculiar species which gave color to it being absent. Our collections, especially from the higher horizons, are unfortunately meager and may give a perverted view of the fauna as it really occurs, but the evidence is such as to demand a consideration, if not the adoption, of the hypothesis that the facies of the Guadalupian fauna is a regional matter denoting not time relations but geographic relations.

There is one more collection made by Mr. Fisher from a limestone in the "Red Beds" northwest of Roswell which represents a still higher horizon than any of the foregoing. The fossils are abundant but represent only two species, *Pleurophorus*? aff. *subcostatus* and *Schizodus* aff. *ovatus*. The *Schizodus* may be the same species which at Cloudcroft I identified as *S.*

Wheeleri and, if so, indicates a connection with the older faunas. The *Pleurophorus* does not seem to show the linear posterior tooth of that genus and its relations are therefore doubtful. It would be unsafe to say anything definite regarding this occurrence. In fact, it might be unwise to assert definitely from intrinsic evidence that it was of Carboniferous rather than Triassic age.

Although not of foremost importance in connection with the subject in hand, it may be well to remark on the lower faunas of the Pennsylvanian in the Sacramento Mountains. These were naturally obtained on the bold western front of the range, chiefly in the vicinity of Alamogordo and La Luz Canyon. Beneath the limestone mass which caps the summit at Cloudcroft there is, as has already been pointed out, an extensive series of sandy strata largely characterized by a red color and belonging to what is generally called the "Red Beds." They comprise, it is estimated, between two and three thousand feet of "Red Beds" and below these, northeast of Alamogordo, some 1500 feet of sandstone, shale and limestone, in which the red color is lacking, but which may be represented by "Red Beds" elsewhere. The collections were made in the lower part of the sandy series chiefly from the basal 1500 feet, but also from some heavy limestones which occur in the lower part of the "Red Beds" overlying. Some of the more important species identified in twelve collections are:

Triticites secalicus
Rhipidomella Pecosi
Enteletes hemiplicatus
Derbya crassa
Meekella striaticostata
Chonetes Flemingi
Productus semireticulatus
Productus punctatus
Productus Cora
Productus Nebraskensis
Marginifera Wabashensis
Marginifera splendens
Dielasma bovidens
Spirifer Rockymontanus
Spirifer cameratus
Squamularia perplexa
Ambocœlia planiconvexa
Composita subtilita
Leda bellistriata var. *attenuata*
Aviculipinna Nebraskensis
Pseudomonotis Hawni
Pseudomonotis Kansasensis
Myalina subquadrata

Allorisma terminale
Plagioglypta canna?
Meekospira sp.
Euomphalus catilloides
Gonioloboceras goniolobus.

It will at once strike the paleontologist that this facies is largely that of the Mississippi Valley Pennsylvanian and very different from the overlying limestone whose base is near Cloudcroft. It is not clear from our collections that the fauna of the limestone does not descend into the "Red Beds" below and there is a suggestion, though as yet a very slight one, of an intergradation or intermingling of the faunas. Yet it will probably remain true, new evidence being discounted, that the lower faunas have much more of a Pennsylvanian facies than the upper.

If we attempt to correlate this fauna with that of Kansas by means of Mr. J. W. Beede's recently published charts, the effort is apparently attended with indifferent success. Many of the species range from the base to the top or nearly to the top of the Pennsylvanian. *Enteletes hemiplicatus*, however, does not appear below the Allen limestone, while *Aviculipinna Nebraskensis* ranges from the Bethany limestone to the Chanute shale. In other words, there either is no evidence because of the long range of the species, or else the evidence is conflicting, for of the two critical species mentioned above, the range of one (*A. Nebraskensis*) ends in Kansas before the other begins; nor is any false premise involved on the part of the western occurrence because of the list being a composite one, for the two species were obtained at the same locality. While better results might attend a more critical comparison of the two faunas, I think it will be safe to say that the evidence will not be obvious in its significance or without contradiction. Tentatively, the horizon indicated seems to be above the lower formations of the Kansas "Coal Measures" and below the upper, within say the limits of Mr. Beede's[1] series II and III, and possibly in the lower rather than the upper part of these limits. On the other hand, *Spirifer Rockymontanus*, which does not occur in the Kansas section at all, suggests a still lower horizon with the still further contradiction of the evidence vested in the two species especially discussed above.

The faunal evidence afforded by our collections is not as complete as is desirable but it indicates no trace, or only the faintest trace, of the typical Guadalupian fauna in those beds which are known to be the continuation of the Guadalupian formations. The imperfectly known faunas which we do find there have no marked relationship to those developed so close at hand

[1] University Geol. Surv. Kansas, Rept., vol. 9, pp. 336, 362 et seq. 1909.

to the southward and are more comparable to the faunas at Cloudcroft, and in the Hueco limestone. This phenomenon may result from several causes, — to a change of facies at the same horizon, or the introduction of different facies at new horizons, etc., but in any event, if the fact thus suggested is substantiated, it seems to render untenable the proposition that the peculiarities of the Guadalupian fauna are due to position in time, which I had employed as a working hypothesis, and of course to make it necessary to abandon the tentative correlations which developed from it. The alternative hypothesis that this facies, remarkable as it is, is due to local conditions would be demanded by the evidence.

On this new interpretation it becomes extremely difficult to determine any exact relationship between the trans-Pecos section and that of the Mississippi Valley. The unique character of the Guadalupian fauna, which at first suggested that it belonged to a later period than any of the Carboniferous faunas of the Kansas section, at least effectually precludes a correlation with that section by means of faunal evidence at present known. A few genera, such as Enteletes, have a characteristic range in the Kansas beds, but they are either absent from the Guadalupian fauna, or, if present, as is the case with the genus mentioned, their evidence can hardly be relied on. The influences which made so many of the Guadalupian genera and practically all of the species different from those of Kansas and even segregated the species of the common genera into altogether different types would hardly maintain the ranges of those genera at the same level but would extinguish them earlier or later in one region or the other. At least the hypothesis of uniformity appears the more improbable.

The typical Hueconian fauna while, as already remarked, it shows far more resemblances than the Guadalupian to the Pennsylvanian faunas of the Mississippi Valley, is yet much more Russian than American in its facies. I noted in my Guadalupian report that it was reminiscent of the earlier rather than the later faunas of the Kansas section, but it also affords no basis for definite faunal correlation. The same is true of the more northern faunas into which Mr. Richardson's work has shown that the Guadalupian faunas are transformed or by which replaced. They have a western rather than an eastern facies and show nothing suggestively analogous to the Kansas faunal sequence. In a brief survey therefore of the faunas of the trans-Pecos region, I find no *point d'appui* in invertebrate paleontology for an exact correlation of the Guadalupian series with the Kansas section. It might correspond to one part almost as well as to another, or it might be above as was my original hypothesis. *A fortiori*, if the Guadalupian faunas do not maintain their characters for one hundred miles to the northward, at least as great or even greater transformation may be expected at equiv-

alent horizons in the Mississippi Valley. If correlated with any part of the Kansas section, the equivalence is presumably with the upper beds, in view of the great thickness of the trans-Pecos series and the general character of the Hueco fauna. The actual relations must be determined by stratigraphic or new paleontologic evidence.

At one point in the preceding discussion it was stated that at the time the Guadalupian fauna was described, no stratigraphic facts were known which tended to determine the relationship of the Guadalupian series to the Carboniferous of the Mississippi Valley. To this statement one exception may be made. W. F. Cummins [1] had already traced the Permian and the Triassic (Dockum group) of central Texas around into the trans-Pecos region, where they were found to occupy a position suprajacent to the Guadalupian. C. N. Gould's work, published as Water-supply Papers of the U. S. Geological Survey,[2] does not bear so much upon this point and was hardly accessible to me at that time, because my report was nearly three years in the hands of the editors, mostly in proof, so that his earliest report must have been coming from the press just as mine was going into it. The failure to discuss Cummins's conclusions in their bearing on the correlation of the Guadalupian beds was due to oversight rather than to an intentional disregard of stratigraphic evidence. Nevertheless, the peculiar and individual features of the Guadalupian faunas were so impressive that I think I should have been disposed to believe that some mistake had been made in mapping the Texas formations since the work was of a reconnaissance nature, since it was without fossil evidence (in fact, when we consider the nature of the Guadalupian fauna, it may in a sense be said to have been contrary to fossil evidence), and since it involved the tracing, over a long distance, of strata peculiarly difficult to follow owing to lithologic changes at the same horizon.

Under present conditions, while the considerations mentioned still obtain, the objection resident in the peculiar facies of the Guadalupian fauna is largely removed by the facts recently brought to hand, and this becomes about the only line of evidence at present available, which links the Guadalupian beds with those of the Mississippi Valley. The result of a summary of this evidence is surprising. In Cummins's terminology the Permian consists of the Wichita, Clear Fork and Double Mountain formations, the latter being the highest. Now, according to the same author, the upper part of the Wichita is the Fort Riley limestone,[3] which is the middle portion of the Chase or basal group of the Kansas "Permian". Consequently, if this tracing is correct, the Guadalupian beds represent a horizon below the base

[1] Geol. Surv. Texas, Third Ann. Rept., p. 211; also N. F. Drake, *idem.*, pp. 227 et seq. 1891.
[2] Nos. 148, 154, 191.
[3] Texas Acad. Sci., Trans., vol. 2, p. 98. 1897.

of the Kansas " Permian " as determined by the Wreford limestone, the basal formation of the Chase group. Bearing on the position in the Kansas section of the *base* of the Guadalupian beds, I have no evidence, but as the latter aggregate 4,000 feet in thickness (overlying strata which are not shown at Guadalupe Point not being included), even if we allow for considerable expansion, the base of the Guadalupian beds must occur considerably below the base of the Chase group.

Furthermore, Gould [1] states that the Quartermaster and Greer formations of the Oklahoma section are probably equivalent to the Double Mountain formation of Texas; the Woodward, Blaine and Enid to the Clear Fork, and the rocks near Chandler (which he refers to the Pennsylvanian) to the Wichita. From this it would appear that the interesting fauna which Dr. Beede described from the Quartermaster formation and the Whitehorse sandstone member of the Woodward formation must occur far above the top of the Capitan limestone.

If the peculiar facies of the Guadalupian fauna seems to be largely due to environmental conditions when compared with those nearby, such correlative value as is lodged in its resemblance to certain faunas in Asia and Europe must also be accepted with caution. These led to a tentative alignment of the Guadalupian with the Artinsk and Permian of Russia. Granted the correctness of the not wholly satisfactory stratigraphic evidence, this would make the Permian of Kansas and Oklahoma largely, or entirely younger than the typical Permian of Russia. Granted, however, the correctness of the plant evidence, which determines the lower portion of the Kansas "Permian" as of Permian age, the Guadalupian would then occupy the position of the Gschelian, and its possible equivalent in India (the Productus limestone), and in Sicily (the Fusulina limestone) would also be Gschelian. As against this stands the fact that the Hueco beds are much more nearly related to the Gschelian than are the Guadalupian, so far as the faunas are concerned, and that the two American formations aggregate over 10,000 feet, which is a rather great thickness to represent the Russian formation.

It will be of interest to give brief consideration to the faunal procession which occupied some of the American areas during the upper Carboniferous. According to the correlation governed by the latest evidence available, the earlier faunas of the Pennsylvanian in the Hueco and Sacramento mountains have a facies in many respects closely simulating the well-known Pennsylvanian of the Mississippi Valley — more Russian in the Hueco Mountains, more American in the Sacramentos. Changing conditions caused a change

[1] U. S. Geol. Surv., Water-supply Paper, No. 154, p. 17. 1906.

in the fauna which made itself felt in the limestone at Cloudcroft or possibly earlier. Still another change of conditions, inaugurated apparently further south, produced the remarkable Guadalupian faunas, organic life in the Sacramento Mountains apparently remaining nearly static. Static conditions seem also to have prevailed in the Mississippi Valley [1] through all this period, and beyond into the "Permian," allowing but slight and gradual faunal developments which did not at any time assume a facies resembling the higher faunas of the trans-Pecos. Later than the Guadalupian and later also than the extinguished faunas of the Kansas section, came those of the higher "Red Beds" of Oklahoma (Whitehorse and Quartermaster). Although my knowledge of the last mentioned faunas and their occurrence is largely second hand, they seem to present such marked differences from the Kansas Permian that it would be well, it seems to me, to consider carefully whether it is appropriate to include them in the same group. These faunal modifications, which are almost without known parallel in the Paleozoic, are certainly, so far at all events as the Guadalupe and Sacramento mountains are concerned, independent of the direct influence of barriers and are apparently to be interpreted upon the basis of environmental influences. At present the area in question seems to offer a field for research in the matter of faunal modifications of the greatest interest and promise.

---

[1] Dr. Beede states that an intermingling of the faunas of the two areas was impossible to a considerable extent after about the horizon of the Topeka limestone (Jour. Geol., vol. 17, p. 679. 1909.)

[ANNALS N. Y. ACAD. SCI., Vol. XIX, No. 7, Part II, pp. 149–160. 15 January, 1910.]

PATAGONIA AND THE PAMPAS CENOZOIC OF SOUTH AMERICA. A CRITICAL REVIEW OF THE CORRELATIONS OF SANTIAGO ROTH,[1] 1908.

BY W. D. MATTHEW.

(Read December 6, 1909, before the New York Academy of Sciences.)

This valuable contribution from Dr. Santiago Roth, of the La Plata Museum, bears throughout the mark of a cautious, able and judicious investigator, thoroughly familiar by first hand observation with the formations discussed, well-acquainted with the European Tertiary faunæ that are chiefly used for comparisons and with the broad principles upon which such correlations have usually been based. Dr. Roth's paper is illustrated by a series of instructive photographs of the formations described, and constitutes a most welcome contribution to one of the most important correlation problems of the present day. He intends soon to present fully the paleontological evidence in his hands.

The age of the later Mesozoic and Cenozoic formations of the Argentine Republic has become a problem of high scientific importance on account of the extraordinarily rich and varied mammalian faunæ which they have yielded.

In more recent years, interest in the fossils of the Argentine has been renewed by the discovery of a series of mammal faunæ older than the Pampean and no less remarkable. The first credit for these later discoveries is due to the tireless energy of the distinguished Argentine paleontologist, Florentino Ameghino, now director of the Museo Nacional of Buenos Aires; who in his earlier years played a large part in obtaining the great Pampean collections of the Paris Museum and the American Museum of Natural History. Finally, in the Museum of La Plata, the efforts of Moreno, Roth and Mercerat have brought together a collection of South American fossil mammals second only to that of the Museo Nacional.

---

[1] S. ROTH: Beitrag zur Gliederung der Sedimentablagerungen in Patagonien und der Pampasregion. Neues Jahrbuch, B. B. XXVI, s. 92–150, taf. XI–XVII Stuttgart, 1908.

Table I.

	Ameghino 1906	Roth 1908	Gaudry 1906
PLEISTOCENE			*Pampean*
PLIOCENE	*Pampean*	IV. *Pampean*	
MIOCENE			*Santa Cruz*
OLIGOCENE		III. *Santa Cruz* and *Patagonian*	*Patagonian*
EOCENE	*Santa Cruz* and *Patagonian*	II. *Pyrotherium*	*Pyrotherium* *Notostylops*
UPPER CRETACEOUS	*Pyrotherium* *Notostylops*	I. *Notostylops*	

A wide diversity of opinion exists as to the correlation of these formations of the Argentine Republic, older as well as more recent. Comparison with European standards is peculiarly difficult on account of the isolation of the faunæ and the lack of corresponding and closely related, not to say identical, genera and species in them. In the absence of such direct data, recourse must be had to more indirect means of correlation,—

First, to the relative stage of evolution shown in the faunæ compared.

Second, to their near or remote relationship to the modern faunæ of the same region, as exhibited in the proportion of extinct to living species, genera and families.

Dr. Ameghino in his correlation places greater weight upon the first, Dr. Roth upon the second means. European and North American paleontologists have in general been indisposed to accept the results of either of these methods at their face value, unless supported by (1) *known stratigraphic relations to marine faunæ,* or by (2) *direct comparison of some nearly related types in the stages to be correlated.*

The question is of necessity a difficult one, and it is doubtful whether it can be securely settled until we know more of the *origin* and *direction of migration* of the various components of the faunæ involved. If, as is the practically unanimous opinion of European and North American writers, the vast majority of the Tertiary and modern mammals *originated* in the North, it is obvious that the *geological age of equivalent stages in most phyla will be later in Patagonia than in the northern world.* If, as Dr. Ameghino believes, Patagonia was the center of dispersal of the majority of Tertiary and modern mammals, the reverse will be true.

In the first case the Patagonian faunæ will be more recent than they seem; in the second case they will be older. And it should be observed that the same will hold true of the marine faunæ, although perhaps the divergence between actual and apparent age will not be so wide. If the majority of groups of marine vertebrata and invertebrata originated along the coasts or in the seas of the northern hemisphere, then the real age of the marine faunæ of the southern seas and coasts will be less than their apparent age; they will be, like the land faunæ, unprogressive and archaic in comparison with their northern contemporaries.

We may review briefly the principal data which Dr. Roth brings forward in support of his correlations:

I. The Notostylops Fauna.

1. Roth confirms positively the assertion of Ameghino that this mammalian fauna is unquestionably associated with Dinosaurs. This means either that it is of Cretaceous age, or that Dinosaurs survived in South America into the Eocene epoch. But the beds in which the Notostylops fauna occurs are, according to Roth, quite certainly of identical age with the marine Roca beds, which are admitted by Wilckens to be Cretaceous. Unless therefore we suppose, as the reviewer has intimated above, that the marine faunæ of the southern coast may be more recent than homotaxial marine faunæ in the northern world, we must admit, apparently, that this fauna is of pre-Tertiary age.

2. He denies the presence of rodents in this fauna, but it includes armadillos "of which some are scarcely distinguishable from those living

to-day." Ameghino has repeatedly insisted upon the great antiquity of the armadillos, and that they represent very nearly the central stock from which the edentate families are descended.

3. All the ungulates are brachyodont; most of them belong to the Notungulata, a group proposed by Roth which is not represented in the northern world. The animals regarded by Ameghino as ancestral to the Ancylopoda or clawed Perissodactyla and to the Equine Perissodactyls, are, according to Roth, early stages in the evolution of the Notungulata and have nothing to do with Perissodactyls.

4. The so-called Creodonts of the early South American faunæ (Sparassodonta) are not really related to the true Creodonts of the northern hemisphere, the resemblances being due to parallelism. Sinclair has demonstrated this very clearly as regards the Sparassodonta of the Santa Cruz fauna.

The reviewer notes with regret that Dr. Roth does not discuss in any detail the relations or comparisons between the apparent Condylarth and Multituberculate element of the Notostylops fauna and the Condylarths and Multituberculates of the Puerco, Torrejon and Cernaysian faunæ of North America and Europe. These groups, although imperfectly known, appear to afford the most important means of comparison with the basal Eocene mammal faunæ of the northern world. Roth is apparently unaware that the absence of rodents is also a marked feature of the northern basal Eocene faunæ. Nor does he take into account the relatively advanced stages of evolution in the Notungulate groups of the Notostylops fauna as compared with anything to be found in the Puerco-Torrejon or Cernaysian. These data appear to us to be important parts of the evidence, which we trust may be duly discussed and considered later.

II. **The Pyrotherium Fauna.**

There has been a good deal of confusion between the Pyrotherium fauna and the preceding Notostylops fauna, which is not yet cleared up satisfactorily. The most characteristic genus is *Pyrotherium*, and, as evidence of more recent age than the Notostylops beds, no association of Dinosaur teeth with this fauna has been demonstrated. The formation is provisionally placed by Roth in the Eocene.

III. **The Patagonian Tuff Formation.**

Under this Dr. Roth includes both the marine Patagonian and the terrestrial Santa Cruz beds. He agrees with Ameghino's more recently

Table II.

SUCCESSION OF SEDIMENTARY STRATA IN PATAGONIA AND THE PAMPAS REGION.

According to Santiago Roth, 1908.

	PATAGONIA		PAMPAS	
V. PATAGONIAN CONGLOMERATE FORMATION	Later glacial morainic, fluviatile and cave deposits, with remains of extinct mammals.	PLEISTOCENE	La Plata delta; fluviatile sediments of the modern rivers; later æolian sands.	PAMPEAN FORMATION
	Older glacial morainic, and late marine sediments on the coast.		*Upper Pampean* Unconsolidated loess, with marine intercalations along the coast, lacustrine beds and older æolian sands. Characterized by occurrence of modern species besides many extinct genera. *Typotherium* is no longer present.	
IV. PATAGONIAN SANDSTONE FORMATION	*Rio Negro Beds* Fluviatile sediments in Rio Negro valley, swamp sediments in the Cordillera and Precordillera, marine sediments at Deseado. Mammalian fauna little known.	PLIOCENE	*Middle Pampean* Consolidated loess with marine intercalations at Ensenada and San Pedro; no recent species, and but few recent genera; *Glyptodon*, *Panochtus*, *Mastodon* and *Typotherium* occur.	
	Santa Rosa Beds Terrestrial sediments of Lago Blanco, marine sediments of Cape Fairweather, Cañadon de Santa Rosa, Sierra Laziar etc. Fauna equivalent to Parana and Monte Hermoso.	MIOCENE	*Lower Pampean* Loess of Monte Hermoso, Mar del Plata, fluviatile and marine sediments of Entre Rios; *Glyptodon*, *Panochtus*, *Machærodus*, *Mastodon* etc., not yet present.	
	Nahuel Huapi Beds Swamp sediments in Cordillera and Precordillera, fluviatile sediments on the table-land and coast (Puerto Madryn). Mammalian fauna unknown.		Swamp sediments 150 ft. below surface at Rufino. ?	SUB-PAMPEAN FORMATION
	Rio Frias Beds Terrestrial sediments near sources of rivers Frias, Aisen, Fenix, Guengel; fauna transitional between Santa Cruzian and lower Pampean.			
III. PATAGONIAN TUFF FORMATION	*Santa Cruz Beds* Terrestrial sediments of Santa Cruz; no modern genera present.	OLIGOCENE		
	San Julian or Patagonian Beds Terrestrial sediments of the table-land from Chubut to Collon Cura; marine sediments along the coast from Punta Arenas to Golfo Nuevo, and in the interior at Rio Deseado, Valle Alsina, and at Corral Foyel in the Cordilleras. *Colpodon* occurs, with Santa Cruzian genera.		Marine sediments 200 ft. below surface at Selva and Timote ?	
	Tecka Beds Terrestrial sediments, Rio Corcobado, Rio Tecka, southward from Paso de Indios (Rio Chubut); *Archæhyrax* occurs, with Santa Cruzian genera.			
II. Transitional beds (Tobas de transicion)	Fauna unknown	EOCENE		
	Colhuapi or *Pyrotherium Beds* Terrestrial sediments of the table-land of Chubut Gobernacion. Occurrence of genera with hypsodont dentition.			
	Fauna insufficiently known			
I. DINOSAUR FORMATION	*Roca or Notostylops Beds* Terrestrial sediments of the table-land of Chubut Gobernacion; marine sediments of Cerro Cazador, Baguales, Sehuen, Golfo San Jorge, Salamanca, Malaspinos, Colhuapi, Rio Chico, Travesia in the Valle de las Plumas, and Roca; all genera with brachydont dentition.	UPPER CRETACEOUS	Red sandstone 200 ft. below surface at Rancul.	

expressed views, as well as with Ortmann, Scott and Hatcher, in regarding them as the marine and fresh-water facies of a single great formation. So far as the age of the marine facies is concerned, he points out the discrepancy in the conclusions of Cossmann, von Ihering, Ortmann, Ameghino and Wilckens as to the age indicated by its fauna, and concludes that the marine fauna is a rather uncertain guide as to the age of the formation. The reviewer ventures to express a corresponding skepticism as regards the marine facies of the Notostylops beds. The correlation is not much more satisfactory when obtained through the terrestrial fauna, large and well known as this is. This fauna is in great part composed of new groups of mammals, which are not directly derivable from those of the Pyrotherium beds; other groups have broadened out or specialized so far between the two epochs as to show that a long time gap intervenes. The intermediate stages recognized by Ameghino between the two are regarded by Roth as not demonstrably more than local facies of the Santa Cruzian fauna.

There are at most three sub-divisions of the Patagonian tuffs. The lowest member, the Tecka beds, contains a limited mammalian fauna of older facies, as shown by the presence of *Archæohyrax* of the Pyrotherium beds, and the continued absence of rodents. The middle horizon includes the main mass of the marine Patagonian, in which Santa Cruz mammals are found locally, mixed with the marine fauna. There are also considerable fresh-water mammaliferous beds in this horizon. The main body of the epicontinental Santa Cruz formation lying to the southward, overlies the marine beds, according to the observations of Carlos Ameghino, and if so, constitutes the uppermost member of the formation.

Much weight is laid by Roth, as also by Ameghino, upon the evidence obtainable from the rodents in correlating the Santa Cruz fauna. In Europe, rodents first appear in the Lower Eocene (Wasatch and Suessonian), in the Argentine their first appearance is in the Patagonian tuffs.[1] All the Santa Cruz rodents are highly specialized forms; the primitive groups of the European Eocene do not appear at all. On the other hand, no modern genera occur in the Santa Cruz, while in Europe a large percentage of the Miocene genera are still living, and many living genera are found even in the Oligocene. The author concludes that this entire absence of living genera indicates an age not later than Oligocene for the Santa Cruz rodentia.

The reviewer would agree as to the value of the rodents in this problem, but would be more inclined to weigh their actual degree of diversity as a whole from the modern rodents, than the rather nominal character of per-

[1] Ameghino, however, records *Cephalomys*, an unquestionable rodent, and a specialized Hystricomorph at that, from the Pyrotherium Beds.

centages of extinct genera. The personal equation of the describer and the imperfection of the types enter so much into the generic reference of extinct species, that correlations on this basis are not very reliable when taken at their face value. Comparisons should also be made with North American rodent genera of the Tertiary epochs and their modern survivors. A further consideration that should be taken into account is that the extensive immigration of northern forms into South America at the end of the Tertiary would naturally have caused a rapid extinction or modification of the native rodent genera with which they came into competition. These considerations have led the reviewer to agree with Scott in ascribing a Miocene and probably late Miocene age to the Santa Cruz rodentia.

IV. The Patagonian Sandstone Formation.

This thick and generally barren formation includes the Tehuelche of Gaudry and the Cape Fairweather Beds of Hatcher. It contains, according to Roth, an admixture of Santa Cruzian and Pampean genera (at Lago Fontana and Lago Blanco). Four subdivisions may be recognized,— Rio Frias, Nahuel Huapi, Santa Rosa (= Cape Fairweather) and Rio Negro beds. The first three are regarded by the author as Miocene, the last as Pliocene.

V. The Pampean Formation.

Roth uses this term in a rather wide or comprehensive sense, including the Parana beds as well as the typical Pampean. He regards the lower part of the Parana formation (= Monte Hermoso beds of Ameghino), as not later than Miocene, the criteria being chiefly the ratio of extinct to living genera. The earliest precursors of the great faunal invasion from North America appear at this point (*Pararctotherium* etc.) but the great mass of the northern invaders (*Canis, Felis, Equus, Mastodon* etc.) first appear in the upper strata of the Middle Pampean, although Cervidæ and Ursidæ appear somewhat earlier. Roth takes exception to the generally held view of the North American origin of the South American species of Equidæ as follows:

> The occurrence of *Equus* in the Middle Pampean is no evidence for the Pleistocene age of these beds. We did not receive the Equidæ from North America, as is often asserted. There occur here contemporaneously three well separated genera, of which two are not present in North America, a proof that they did not reach us from there. The genus *Equus* occurs as early as the Siwalik beds of India [which Roth accepts as Lower Pliocene]. Among all the immigrant mammals which occur in the uppermost beds of the Middle Pampean there is no single genus which does not occur in the Northern hemisphere as early as the Miocene.

The author considers that the Equidæ reached South America from the Old World by way of a South Atlantic land bridge.

Roth's argument does not appear convincing to the reviewer. Against it may be briefly noted the following:

1. Any other source than North America for the invading fauna involves geographic changes of a highly improbable character.

2. The existence of a land bridge between Africa and South America in the late Tertiary would almost certainly involve a community of fauna between the two continents which does not exist.

3. The counter-migration from South America took place to North America and to North America only. It occurred chiefly at the end of the Pliocene, as recorded in the North American faunal succession; but doubtful precursors are found in the Middle Miocene (Mascall[1]) and Lower Pliocene (Snake Creek[2]) of North America.

4. There is no difficulty in the derivation of all the South American Equidæ from the more primitive North American Equidæ of the late Miocene and Pliocene (*Protohippus, Pliohippus, Neohipparion*).

5. The Siwalik fauna is more or less composite and includes Pleistocene as well as Pliocene species. It is doubtful whether any considerable part of it is Miocene.

6. The Pampean *Canis, Felis, Smilodon, Mastodon* etc. are most nearly related to late Pliocene and Pleistocene species of the north, and especially of North America. The so-called *Canis* and *Mastodon* of the northern Miocene are much more primitive forms, well separable generically.

7. All the genera of northern origin recorded from the Middle Pampean are identical with or equivalent to the Pleistocene genera of North America, and decidedly more advanced than the Upper Miocene and Pliocene genera of this continent. *Equus, Tapirus, Cervus, Mastodon, Arctotherium, Canis* and *Smilodon* first appear in North America in the Pleistocene. *Hippidion* and *Onohippidion* are equivalent in specialization to *Equus*, and are derivable from the much more primitive *Pliohippus* and related genera of the Upper Miocene and Pliocene. The so-called *Listriodon* and *Catagonus* of the Pampean are closely related to *Platygonus* of the Pleistocene and *Prosthennops* of the Upper Miocene and Pliocene of North America. *Auchenia* and *Palæolama* are equivalent in specialization to the Pleistocene camels of North America, decidedly more advanced than the Upper Miocene and Pliocene *Procamelus, Alticamelus* and *Pliauchenia* of this country. The same relations appear in the Pampean Cervidæ. Among the Felidæ *Smilodon* is found only in the Pampean and in the North American Pleisto-

[1] Sinclair, 1906.
[2] Matthew and Cook, 1909.

cene; it is unknown from the Old World; *Felis* is doubtfully identified in the Middle Pliocene (Blanco), certainly present in the Pleistocene of North America.

From these data it appears to the reviewer that the northern elements of the Middle and Upper Pampean fauna were derived, certainly in large part, probably entirely, from North America, by a migration not earlier than the beginning of the Pleistocene. The Lower Pampean may however be considerably older; its few northern genera — *Pararctotherium, Pachynasua, Cyonasua, Microtragulus* etc., are aberrant or imperfectly known forms of more archaic aspect, approximately derivable from the Miocene carnivora etc. of North America, but decidedly more specialized.

CHARACTERISTIC GENERA OF THE SOUTH AMERICAN CENOZOIC WITH PROVISIONAL ORDINAL REFERENCES (W. D. M.[1]).

I. Notostylops Fauna.

Marsupialia (Polyprotodontia).
Caroloameghinia (with *bunodont* molars).

Marsupialia (Diprotodontia, ? Multituberculata).
Propolymastodon.
Polydolops, Orthodolops, Pliodolops.

Edentata (Dasypoid genera only).
Meteutatus etc.

Condylarthra (including genera allied to Periptychidæ).
Didolodus (cf. *Ectoconus*, but with quadrate molars).
Ricardolydekkeria, Gulielmofloveria (cf. Anisonchinæ).
Asmithwoodwardia, Notoprotogonia (cf. *Euprotogonia*).
Proectocion (cf. *Ectocion* and *Phenacodus;* also cf. Litopterna).
Nephacodus, Lonchoconus (cf. *Phenacodus*).
? *Henricosbornia.*

Litopterna (primitive brachyodont genera of)
Lambdaconus (astragalus certainly Litoptern).
? *Archaeohyracotherium*, ? *Oldfieldthomasia* (cf. also Toxodontia).

Toxodontia (incl. Typotheria, primitive genera of)
Notopithecus.

Insectivora.
? ? *Selenoconus* is stated by Ameghino to be closely allied to *Hyopsodus*, which is a very generalized animal of remote insectivore relationships. It is known only from part of the lower jaw.

[1] The geological occurrence of the genera is based chiefly upon Ameghino's published lists (1908). The reviewer is responsible for their systematic reference.

Incertæ sedis.

Trigonostylops; *Notostylops*. These genera are fairly well known, but their affinities with any of the recognized orders are not very clear, and certainly not close.

Homalodotheria.

Albertogaudrya.

II. Pyrotherium Fauna.

Marsupialia (Polyprotodontia).

Pharsophorus (Borhyænidæ).

Marsupialia (Diprotodontia).

Parabderites, *Pseudhalmariphus* etc. (Epanorthidæ).

Rodentia.

Cephalomys (Hystricomorpha, dentition quite progressive).

Edentata.

Peltephilus, *Prodasypus*, *Palæopeltis* (Dasypoid and Glyptodont genera; Gravigrada rare).

Homalodotheria.

Asmodeus, *Leontinia.*

? *Rhynchippus* (cf. also Toxodontia).

Pyrotheria.

Pyrotherium, *Liarthrus.*

Astrapotheria.

Parastrapotherium etc.

Litopterna.

Deuterotherium, *Protheosodon* etc.

Toxodontia (including Typotheria).

Propachyrucos etc.

Archæohyrax etc.

Hegetotheriidæ, Eutrachytheriidæ.

III. Santa Cruz Fauna.

Marsupialia (Polyprotodontia).

Microbiotherium, *Eodidelphys* (related to *Didelphis*).

Borhyæna, *Prothylacinus*, *Cladosictis*, *Amphiproviverra* etc.

Marsupialia (Diprotodonta).

Epanorthus, *Abderites*, *Acdestis*, *Callomenus*, *Garzonia*, *Halmariphus*, *Stilotherium*. (Epanorthidæ, related to *Cænolestes*).

Primates.

Homunculus etc.

Insectivora.

Necrolestes (Chrysochloridæ).

Rodentia.

Steiromys, Acaremys, Sciamys, Neoreomys, Spaniomys, Perimys, Eocardia (all extinct genera, but quite closely related to modern South American Hystricomorpha.

Edentata.

Hapalops, Schismotherium, Planops, Analcitherium etc. (Gravigrada).

Propalæohoplophorus, Cochlops, Eucinepeltus (Glyptodontia).

Prozaëdyus, Proeutatus, Stegotherium, Peltephilus (Dasypoda).

Homalodotheria.

Homalodotherium.

Astrapotheria.

Astrapotherium.

Toxodontia (including Typotheria).

Nesodon, Adinotherium (Toxodonts).

Protypotherium, Hegetotherium, Interatherium (Typotheres).

Litopterna.

Proterotherium, Diadiaphorus, Thoatherium (Proterotheriidæ).

Theosodon (Macraucheniidæ).

IV. Pampean Faunæ.

A. Lower Pampean.

The Lower Pampean of Roth includes, broadly, the 1) Entrerian, 2) Rio Negrean, 3) Araucanian and 4) Hermosan faunæ of Ameghino.

These appear to be in the main the Pampean fauna with successively decreasing proportion of surviving Santa Cruz genera, and with a very scanty number of northern genera, which are related to the Tertiary rather than to the Quaternary faunæ of North America. Among the Carnivora may be noted

Procyonidæ.

Amphinasua, Pachynasua, Cyonasua (cf. *Leptarctus*).

Ursidæ.

Pararctotherium.

Canidæ.

Amphicyon (generic reference questionable).

Ameghino reports Hyænodontidæ, but the specimens figured appear to be carnivorous marsupials, not Creodonts.

The Rodents are all Hystricomorphs except *Argyrolagus*, which is perhaps an abnormal type of *Lepus*.

No Artiodactyla except *Microtragulus* (cf. *Hypisodus* and other Hypertragulidæ).

In the lowest level (Entrerian) the admixture of Santa Cruz genera is large, forming the major part of the fauna.

B. Middle and Upper Pampean.

This is the Pampean (Ensenadan and Bonærian) of Ameghino.

Carnivora.

Smilodon, *Felis*.
Canis, *Palæocyon*, *Dinocynops* (cf. *Lycaon* [1]).
Arctotherium, *Pararctotherium*.
Conepatus (in upper levels only).

Rodentia.

Cricetidæ (*Necromys* etc.).
Dolichotis, *Viscaccia*, *Hydrochœrus*, *Ctenomys*, *Myopotamus* and other Hystricomorph genera, mostly still living.

Edentata (Gravigrada).

Megatherium, *Mylodon*, *Lestodon*, *Glossotherium*, *Scelidotherium*.
(Glyptodontia.)
Glyptodon, *Panochtus*, *Dœdicurus*, *Hoplophorus* etc.
(Dasypoda.)
Dasypus, *Zaëdyus*, *Tatusia*, *Eutatus*, *Chlamydophorus* etc.

Proboscidea.

"*Mastodon*" (all *Dibelodon*, auct. R. S. Lull).

Toxodontia.

Toxodon.
Typotherium and *Pachyrucos* in lower beds only.

Litopterna.

Macrauchenia.

Perissodactyla.

Tapirus in lower levels.
Equus only in upper levels.
Hippidion, *Onohippidion* (derivatives of *Pliohippus* of North America).

[1] The occurrence in the Pampean of a species so closely allied to the South African genus *Lycaon* might seem evidence for a South Atlantic land bridge in the late Tertiary, but in fact, *Lycaon*, *Icticyon* and *Cyon* of S Africa, Brazil and the East Indies are survivors of a group of Canidæ well known from the Oligocene and Miocene of North America. *Dinocynops* is in all probability a fourth descendant of the same group. All are distinguished by trenchant heels on the lower molars, disappearance of intermediate cusps on upper molars, tendency to reduce the tubercular dentition, short deep muzzle, and various other characters. *Palæocyon* Lund (not of Ameghino) is perhaps a member of the same group.

Artiodactyla.

"*Listriodon*" (cf. *Platygonus* in part, *Prosthennops* in part).
Catagonus (cf. *Prosthennops*) in lower levels.
Tagassu (*Dicotyles* auctorum) in upper levels.
Palæolama etc., all close to *Auchenia*.
Paraceros, Odocoileus etc., all close to *Odocoileus* and *Mazama*.

[ANNALS N. Y. ACAD. SCI., Vol. XIX, No. 8, Part II, pp. 161–204, Pll. XV–XX.
1 February, 1910.]

THE COAL BASIN OF COMMENTRY IN CENTRAL FRANCE.

BY JOHN J. STEVENSON.

(Read in abstract before the Academy, 6 December, 1909.)

CONTENTS

INTRODUCTORY NOTE.

The Commentry coal field in central France was described more than twenty years ago by M. Henri Fayol. His work,[1] the result of studies continued during more than twenty-five years, has never been excelled in its

[1] Études sur le terrain houiller de Commentry. Ire. partie. Lithologie et Stratigraphie. par Henri Fayol. Bull. Soc. Ind. Min. 2me. serie, XV, liv. III et IV. Saint-Étienne. 1887. An admirable synopsis was presented to the Geological Society of France in 1889. This, with contributions by other geologists, is in the bulletin of that society, 3me. serie, XVI. These discussions were published separately as Réunion extraordinaire dans l'Allier. This will be cited in the following pages as Réunion etc. and the original work as Commentry.

consideration of detail. The basin is of insignificant extent, but the phenomena observed there have been recognized by students as almost equally characteristic of the other small basins within the central plateau, so that Fayol's work is accepted as one of the most important contributions to French geology.

The author's generalizations respecting the formation of coal beds, based as they were on such a mass of detail, so conscientiously recorded, had weighty influence in converting a great number of geologists from belief in accumulation of coal *in situ* to belief in the contrary doctrine of accumulation by transport. Fayol's presentation of the case appears in many ways conclusive, but, in studying the work, the writer found that some points are so obscure that he could not make intelligent use of it in the preparation of a monograph on which he is engaged. It appeared necessary to make a visit to the locality to gain direct acquaintance with the conditions; and this was done in August, 1909, with full expectation that at Commentry there would be the opportunity to study a coal bed formed of transported material. The writer's examination was confined to the enormous excavations made in mining the coal by stripping.

The generalizations made by Fayol are familiar to all geologists who study coal deposits, but his publications have become comparatively rare and the arguments on which his conclusions were based are known now to few students outside of France. It is well to present a description of the area, based on the writer's observations and supplemented by citations from Fayol. The more so, because in respect to several matters of varying importance, the writer's conclusions differ materially from those of that author.

Description of the Region.

The city of Montluçon, on the river Cher, is about 130 miles south from Paris and about 10 miles west-northwest from the little city of Commentry. De Launay's map [1] of the region shows that between Montluçon and Moulins, 60 kilometers east-northeast, there is a double trough, the divisions being separated by a granite ridge. The northwesterly division contains the petty basins of Commentry, Montvicq and Villefranche in a distance along the strike of about 40 kilometers, the intervening spaces being filled in great part by granite. De Launay concludes, on evidently indisputable grounds, that these divisions and subdivisions were made just prior to Coal Measures time and that the measures in the several basins are not fragments of a once

[1] Réunion etc., Pl. XXXVII.

continuous deposit, but that they were always distinct. His conclusions were confirmed by Fayol's studies in Commentry and Montvicq.

In going southward from Paris by way of Orleans to Montluçon, one rises by a succession of broad benches until, at the latter city, he is on an extended alluvial plain, 214 meters above tide. There the valley of the Cher is bounded at the east by a bold wall with almost level crest, clearly the edge of a higher bench. The railroad to Commentry, quickly leaves the Cher valley, enters a close gorge in granitic rocks, up which it climbs with difficult grade to the station of Chamblet-Néris, 307 meters above tide. Just before that station is reached, the rock changes from granitic to sedimentary, the gorge opens into cultivated territory and one sees, on both sides, flat-topped hills marking a higher bench. This is reached at Commentry, where the station is 375 meters above tide, or 525 feet above Montluçon. The highest plain within the eastern part of the basin is about 400 meters above tide or approximately 600 feet above Montluçon. Points on the border of the basin attain, according to Fayol, 450 meters, but they are projections of granite. Within the basin, on the northern and eastern sides, one finds these three well-marked base-levels at 400, 375 and 307 meters above tide, while covering the whole surface is a deposit of recent gravels seldom more than 15 feet thick.

The Commentry Basin.

The basin of Commentry, according to Fayol,[1] is about nine kilometers long, averages about three kilometers wide and is about 700 meters deep — the longer axis being rudely east and west. De Launay's map, already referred to, shows that the northern border is a narrow strip of mostly mica schist, behind which is granite to the little basin of Montvicq, six kilometers distant. This strip of schist bends around the eastern end, but there one finds behind it, not granite, but a broad band of gneiss, which extends westwardly along the southern border for about three kilometers. But along the rest of the southern border as well as at the west, the sedimentary rocks are cut off abruptly by the granite, which extends almost to the alluvial plain of the Cher. The region southward from the basin of Commentry rises rapidly and appears to be mountainous, but toward the north, as already stated, the surface falls off in a series of steps toward the sea.

Fayol states that at the northwest corner of the basin there is a small area of Permian rocks, but elsewhere only those of the Coal Measures are found, with a thin layer of alluvial material covering the surface. He

[1] Commentry, p 21.

ascertained that there are five distinct zones or areas of deposit, in each of which the material has its special features; these are not successive, but are distributed geographically and merge laterally; they are of synchronous origin. Three of these zones, Longeroux at the east, Montassiégé midway and Bourdesoulles at the west, contain for the most part, coarse materials; while the zone of les Pégauds, between Longeroux and Montassiégé, and that of les Ferrières, between Montassiégé and Bourdesoulles, contain mostly fine materials. The several areas extend from north to south, except that the two containing fine materials are cut off at the north by a narrow strip of coarser beds lining the basin on that side.

Coal is confined, practically, to the areas of finer deposits. In these

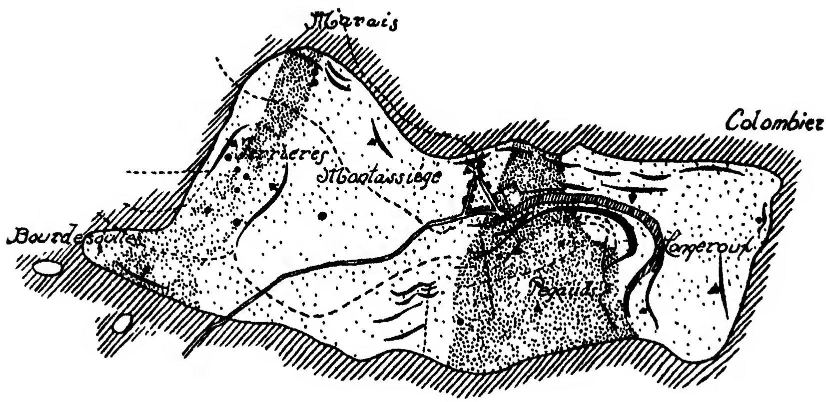


FIGURE 1 THE COAL BASIN OF COMMENTRY.

The heavy black lines indicate coal. This map differs from that in the original work in the extent of the Pégauds and Ferrières areas: the original map made those embrace the whole of the great bed in each case — and in that respect is the more nearly correct.

the lower rocks, 500 to 800 meters thick, are almost barren, containing only a few irregular streaks of anthracite, which appear to be without commercial importance. The coal is mainly in a single bed within each area, which has a curved outcrop rudely resembling the letter "C," and thins southwardly so as to disappear midway in the basin. Near the northern outcrop, each bed attains an enormous thickness, at times more than 60 feet; the southern boundary is defined approximately by a line joining the extremities of the outcrop. The rocks above the great coal bed in each area are reported to be increasingly coarse but are interrupted by shale carrying coal. They nowhere become as coarse as the beds of the other areas. The extent and distribution of the several zones or areas are shown in Figure 1, which is based on

that given by Fayol in the Réunion, etc.; this shows also the outcrops of the coals as well as that of the strange mass, known as the Banc de Sainte-Aline.

The writer's observations were confined wholly to the area of les Pégauds. The principal coal bed is the Grande Couche; above that, at varying distance, is a coal-bearing deposit known as the Grès Noirs, and still higher is another, that of les Pourrats. These are all one bed on the eastern side near the southern limit of the coal, but they separate westwardly, and toward the Montassiégé side the vertical interval is several hundred feet. The Grande Couche, now reached by a deep shaft, was mined for many years in open quarries, or tranchées, beginning at the crop and following the coal by removal of cover. At the depth of 40 to 60 meters, stripping ceased and stopes were driven on the coal. These quarries are almost continuous along the thicker portion of the outcrop and are of vast extent. The photograph of the Tranchée de Forêt (Plate XV, figure 1) suffices to show the general character, though it is one of the narrower and less imposing. Several of the quarries have been abandoned and they are utilized as receptacles of waste from the mine and washeries as well as from the iron works in the city of Commentry.

Description of the Openings.

The great quarries or trenches follow the curved outcrop of the Grande Couche; those on the eastern side are, for the greater part, still in good condition and mining is carried on to some extent in all but one. It is best in the description to begin midway and to study first the trenches on the eastern side; afterwards to examine those on the westerly side, where mining operations have ceased.

Tranchée de Saint-Edmond.

The Tranchée de Saint-Edmond, beginning at a few rods west from the present mine, is 160 feet deep and several hundred feet long. No serious work has been done in it for many years, and the waste dump at the west end has cut off much of its original length. The width at bottom varies from somewhat more than 100 feet at the west to barely 50 feet at the east end.

The Grande Couche is covered by the dump at the west but is still to be seen in the tunnel leading into the Grande Tranchée, and the top of the bed is reached on the floor at the foot of the south wall. The dip here is approximately S. 30° W., and the wall, consisting of shale and sandstone, is sheer from bottom to top. At this end, a succession of sandstones, with thinner

beds of shale, in all about 30 feet,[1] begins at a few feet above the coal. The lower half of this mass disappears within 100 feet. There is no replacement, but simple thinning and the underlying shale is brought into contact with the upper part of the sandstone. As the lower portion approaches the place of disappearance, it becomes irregular and, on the weathered surface, resembles a contorted schist. This thinning is in the direction of the strike, and there seems to be no variation in the dip. The change is wholly in the sandstone, as though the shale surface were inclined when the upper beds were deposited almost horizontally. Owing to this thinning, the upper beds are brought nearer to the Grande Couche. Similar variations appear frequently on this wall and they have been emphasized properly by Fayol as evidence of delta deposit. They have been accepted as such proof by American geologists for at least half a century.

The upper portion of the sandstone persists to the east end of the trench where the floor rises to its level. It is light gray, has much feldspar, is moderately coarse grained with occasional pebbles and contains abundance of stems and leaves, whose position bears no definite relation to the plane of bedding. It holds also many lentils of coal, from mere films to one which is four feet long with greatest thickness of 10 inches. A sandstone, on the northerly wall and at only a few feet below the coal bed, is coarse, with pebbles as large as a pea, but not numerous enough to make the rock a conglomerate.

The Grande Couche is shown imperfectly at the east end of the trench, where one sees the tunnel in the coal, leading to the next trench beyond. The coal is almost 30 feet thick here and, according to Fayol,[2] the thickness in this trench varies from 10 to 12 meters. The exposure of the lower portion suffices to show the presence of irregular plates of rock. A dike of igneous rock, termed dioritine or micaceous prophyry by Fayol, appears at this end, but the exposure is so incomplete that nothing can be ascertained respecting its extent. Where that rock cuts through the Grande Couche on the south wall, the coal laminæ are bent upward at nearly right angles and the metamorphism seems to be complete. The luster is graphitic at two feet from the contact, but at five feet the change is barely perceptible to the eye. Fayol states that for nearly 200 meters along the strike, the coal is so altered that it can be ignited only with difficulty. A rock of similar type is shown near the bottom of the coal bed on the opposite wall.

[1] The thicknesses given for rocks in the walls are all estimates, as direct measurements cannot be made.

[2] Commentry, p. 263.

Tranchée de Forêt.

The eruptive rock just mentioned is present as a broad projecting dike on the surface between Saint-Edmond and the next trench, known as the Tranchée de Forêt, which is not more than 400 feet farther along the outcrop. This long trench of Forêt is reached by a shallower, narrower excavation, termed by the miners the "Tranchée du massif." The only work in progress here is upon the lower part of the Grande Couche, known as the Banc des Brouillages, of which mere traces were seen in Saint-Edmond. It consists of alternating beds of coal and rock, each from one to two feet thick and forms the northerly wall of the trench. This deposit would be ignored in the Appalachian field as commercially worthless, but at Commentry the coal is saved. The steep dip makes winning of the coal less expensive, as the upper part of the bed has been removed; the rocky plates are stripped off easily and the amount of coal obtained comes to some thousands of tons per acre. The sandstone below this bed is rather coarser than in Saint-Edmond.

The Banc des Brouillages forms the northerly wall of Forêt throughout. The dip of the beds, as shown in the easterly wall of the trench, varies little from 30 degrees and the succession seems to be regular. The Grande Couche is well exposed, being mined in a long open cut as well as by two slopes. The succession is, descending:

		Feet	Inches
1.	*Shales*	Not measured	
2.	*Coal*	0	0–6
	This, exposed in the wall at the end of the trench, is merely a lentil. In that wall it is six inches thick, but at 150 feet away along the southerly wall it is but one inch; within a few feet farther, it breaks into a line of isolated nodules and disappears.		
3.	*Shales*	25	0
	Grayish, fine grained, mostly well laminated and some layers are almost fissile; in part, especially in the lower portion, these shales are carbonaceous and impressions of leaves are not rare.		
4.	*Coal: Banc du toit or Banc supérieur*	5–6	0
	This is variable in thickness as well as in composition and shows pockets of shale in which are streaks of bright coal. The upper part is cannel shale or shaly cannel and it too contains streaks of bright coal. The passage to the overlying shale is very gradual and the coal as a whole is of inferior quality.		
5.	*Banc des Chavais, Banc noir of the miners*	9	7
	No trace of this parting appears in Saint-Edmond. As seen here, it is an irregularly bedded deposit containing great numbers of rock fragments, angular or rounded and from one to four inches across; lentils of coal are abundant, one inch to two feet long, but rarely more than two inches thick. The upper portion passes		

		Feet	Inches
	gradually into No. 4, while at the bottom the deposit becomes more and more carbonaceous and is continuous into the coal below. The Banc des Chavais changes quickly toward the west, for long before the middle of the trench has been reached, this thick parting has been replaced by shale, carbonaceous shale and coal. The gradual passage was exposed at the time when Fayol's work was published; now it is concealed by débris, but exposures are complete midway in the trench and there the parting is wanting.		
6.	*Coal; Banc intermédiaire*	9	5
	Here one finds numerous partings, one of them two inches thick and consisting very largely of mineral charcoal (fusain). The coal shows the ordinary variations observed in thick beds, for here are the dull layers alternating with bright laminæ and occasionally a little pot of cannel is seen. The long open pit at the easterly end of the trench shows the erosion of this division, to which Fayol[1] refers. Unfortunately the exposure shows this for little more than a score of feet, not enough to exhibit all of the features, and one is not justified in attempting to explain its cause. But, whatever the eroding agent may have been, it worked in a curious way; for the upper surface of the coal is angular, jagged and pockety. The whole of the upper part was not removed everywhere, for a foot of the top remains, at one place, undercut for several feet. The character of the upper surface suggests that the work was done after the coal had become well consolidated. The bed has been replaced by imperfectly consolidated stuff like that from a collapsed roof. If the exposure were merely an outcrop, one would think this rubbish only the remains of a comparatively recent slip; but this is a fresh exposure on the edge of the mass, which is reported by the miners as extending more than 150 meters along the strike.		
7.	*Shale, Banc des Roseaux*	6 in. to 1	6
	A more or less sandy, light-colored to drab shale, very variable in thickness and containing great numbers of plant impressions beautifully preserved.		
8.	*Coal, Banc inférieur*	11	9
	In great part, this is good coal, but it has many and irregular partings, sometimes becoming so thick as to detract seriously from the worth of the bed. The lower limit cannot be determined, for the rocky plates and lentils increase and there is gradual passage to No. 9.		
9.	*Coal and rock, Banc du mur, Banc des Brouillages*	6	0
	The thickness as given is only approximate. The mass is similar to that seen at the extreme west end of the trench and consists of alternating layers of coal and clay or sandy clay, with here and there some rather coarse brecciated beds. Midway in this trench the whole of this division has been removed and sandy clay is exposed, as follows.		

10. *Sandy clay.*

Only the surface was seen and the thickness could not be ascertained. This surface is irregular, hummocky, with numerous saucer-like depressions, several feet across and filled with coal. At one place this north wall shows a great step in the clay, as though the material, before consolidation, had been piled up against some obstacle. The clay contains vast quantities of carbonized plant remains but no fragments of *Stigmaria* were observed in a space of 20 by 30 feet. Underclay of the ordinary type is wanting here.

Leaving the trench by a stairway on the southerly side, one finds no trace of the Saint-Edmond sandstones, though they are present at the extreme west end. Instead there are mostly more or less sandy, fine-grained shales with occasional bands of fine-grained sandstone, in which are rounded pebbles of shale, carbonaceous shale and even of coal. At 85 feet, by barometer, above the Grande Couche, one finds

Sandstone,	8 to 10 feet

which has many streaks of coal as well as rounded pebbles of shale and coal. This sandstone is not reached in Saint-Edmond, though the wall there rises to 150 feet above the coal bed, but it is shown in the Tranchée de Goutilloux, at a little way southward. In Forêt, the interval, measured without regard to the dip, is less than half that at the west end of Saint-Edmond, so that the thinning in this direction is not confined to the sandstones seen there. This highest sandstone of Forêt is the lower portion of the Grès Noirs group, which becomes important along the eastern outcrop. It is very irregular in Forêt and at times it shows pots of shale with almost concretionary structure. One of these has a bit of sandstone as the core.

Just below the Grès Noirs, the wall shows a feature, often observed elsewhere in a fragmentary way, but here exposed for a hundred feet or more. The sandstone rests on a bed of shale and both describe some gentle flexures; next below is a bed of shale, whose upper surface accords with the flexures, but the lower surface as shown in the wall is straight and rests on a bed of alternating thin shales and sandstones which has been pushed into many petty folds, not shared in by either overlying or underlying beds. The relations seem to suggest that during some disturbance the plicated bed, softer than those adjoining, bore the brunt of pressure and became flexed while the adjoining beds merely moved in mass.

The presence of waterworn pebbles of coal and shale in the shales and in the sandstone of the Grès Noirs has been taken, very properly, as evidence that, by the time that the Grande Couche was complete, a by no means inconsiderable part of the original lake had been so far filled as to be exposed to

erosion. Pebbles of this kind are not confined to rocks above the Grande Couche or to the area of les Pégauds. Fayol states that they occur in the lower division of the coal measures as well as in the higher division within both les Pégauds and les Ferrières. In an interesting comparison, he shows that the coal of the pebbles resembles that of the vicinity. Those near the anthracite of the lower division are anthracite; those near the Grande Couche are of fat coal, though, as should be expected, an occasional pebble of anthracite appears among them; while in the area of les Ferrières they are feebly coking as is the coal of the main bed in that area.[1]

Tranchée des Chavais.

At a few rods beyond Forêt is the abandoned trench of the Chavais, in which the two partings of the Grande Couche — Banc des Chavais and Banc des Roseaux — were found in fine development. But this trench has been abandoned for many years; it is filled in great part and vegetation covers much of the decayed wall, so that little of interest remains exposed. A walk of two minutes brings one to the Tranchée de l'Espérance.

Tranchée de l'Espérance.

The enormous excavation which is known as the Tranchée de l'Espérance is on the eastern prong of the outcrop. Mining operations continue here and the exposures on all sides are still nearly complete. The pit is almost 100 feet deep, not less than 500 feet long and, in places, fully 200 feet wide at the bottom. Nearly all of the curious features described by Fayol twenty years ago are distinct to-day, while advance in the work has brought others into sight, which serve in some cases to make the conditions clearer but in others only more perplexing.

Entering the trench at the northerly end, one finds at 70 feet, by barometer, above the Grande Couche, a thin streak of coal underlying the soft basal sandstone of the Grès Noirs. Below this are gray shales with thin streaks of soft whitish sandstone or very sandy shale. One bed has many pebbles and fragments of sandstone, and around the latter the structure of the shale is as though it had been deposited in an eddy. Here and there one sees fragments of dark shale, and pebbles of coal are not rare.

It is deserving of note that none of the coal pebbles found by the writer showed any signs of contraction after burial; all the pebbles, coal and shale alike, were so securely fastened that removal without fracture was difficult.

[1] Commentry, p. 141.

They were taken out whole only by careful picking away of the surrounding rock. Nor was any of them coated by material which could be regarded as the filling of a cavity; they were in direct contact throughout with the inclosing rock, as were the fragments of sandstone or of ordinary shale. Other observers have found pebbles giving clear evidence of contraction, but the writer is convinced that there are many pebbles which give no such evidence, which must have been torn from a bed of coal. This is not unimportant, for these pebbles have not always the same composition as the neighboring coals and some of them are almost lignitic.[1]

As one descends the stairway, he approaches the Grand Couche and finds

		Feet	Inches
1.	*Shale*	6	0
	This is hard, black, laminated and carries many films of bright coal; it is rich in carbon throughout.		
2.	*Shales*	13	0
3.	*Coal, Banc supérieur, Banc du toit*	6	0
	This consists of Cannel shale, 2 feet, 4 inches, Shale with films of coal, 1 foot 6 inches; Coal, 2 feet 2 inches. The top shale is decidedly bony, laminated in part and, as is usually the case with such shale, carries streaks of bright coal; the middle shale varies from almost wholly impure bright coal to almost wholly dark shale, while the coal below is of poor quality and broken by many clay partings.		
4.	*Banc des Chavais*	6–7	0
	This, for the most part, is of very dark color, so that the miners call it the Banc Noir. As in Forêt, it consists of transported fragments, varying from mere grains to blocks, one foot or more in diameter. Sandstone, gneiss, granite and quartz were seen, all waterworn, though some have the angles only rounded, there is much coal, especially in the upper part, so that the passage to No. 3 is nowhere abrupt. At one exposure, the upper portion is almost wholly coal, in which are imbedded occasional pebbles, several inches in diameter. The bottom foot or 15 inches is a dark shale passing gradually into the next subdivision.		
5.	*Coal, Banc intermédiaire*	10	9
	This has a three-inch parting at 14 inches from the top. Midway in the trench, an exposure shows four feet of coal above this parting, the increase being due to decrease in the Banc des Chavais. The coal is very good throughout; it contains many partings, some of them composed largely of mineral charcoal (fusain).		
6.	*Banc des Roseaux*	2–4	0
	Mostly argillaceous, but varying in composition as well as in thickness; the color is light gray, weathering yellowish; the bedding		

[1] Fayol: Commentry, p. 168.

		Feet	Inches
	varies from regular to indefinitely cross-bedded; remains of plants abound; they were deposited in accord with the bedding, where that is regular, but elsewhere in all directions, with or across the lamination.		
7.	*Coal, Banc inférieur* . . . . This is less easily separated from the portion below than in Forêt; the partings are many and the lenses of sand and clay are more numerous. At some exposures, these lenses are so abundant and extensive that one could easily regard the whole deposit below the Banc des Roseaux as belonging to No. 8.	5	7
8.	*Coal and rock, Banc des Brouillages* (seen) . . . . This has the same characteristics here as in Forêt. The surfaces of its rock layers are broadly wrinkled.	5	0

The Banc supérieur is not mined. At all exposures in the several trenches, it shows the same irregularity of structure and the same abundance of mineral matter. It is exposed for a long distance at the foot of the westerly wall, where it is from three to seven or eight feet thick, and the upper surface is so irregular that one could well imagine himself looking at the cross section of hummocks. The many petty faults and breaks in the bed along this exposure are due mostly, no doubt, to removal of the coal below, but the hummock-like form is not due to that cause for it is equally distinct where the main coal is still in place. An open cut, midway in the trench, represented by Plate XV, figure 2, shows this feature of the bed. In that opening one finds

		Feet
1.	*Banc intermédiaire*	14
2.	*Banc des Roseaux*	2 to 6
3.	*Banc inférieur*	11
4.	*Banc des Brouillages* (seen)	2

The middle division is exposed in an almost vertical wall, so that exact measurement could not be obtained. The Banc des Roseaux is thin towards the present outcrop but thickens down the dip — a somewhat unexpected condition. The Banc inférieur seems to be mostly good coal and contains very few of the sandy lenses, which are so abundant at less than 300 feet away. It is separated from the Brouillages by a bed of shale.

The Banc des Chavais has become very indefinite at this exposure and at another, only 30 feet farther, it has disappeared so that the middle and upper beds are continuous; still farther is another, showing at least 18 feet of coal above the Banc des Roseaux.

This trench was carried down to its present depth on the coal and then the bed, dipping at 20 degrees and upward, was uncovered by stripping in a space more than 100 feet wide. The Banc inférieur is exposed along the easterly side for not far from 100 feet in a shallow trench, where it is folded

along the strike and faulted in at least two places. The Banc des Brouillages is shown on the easterly wall.

The conditions between the present workings and the original outcrop cannot be ascertained now, as the rocks have been removed, but Fayol[1] reports that some beds of shale seen, when he wrote, at the bottom of l'Espérance, thickened and multiplied toward the outcrop so that, within 200 meters, the great coal bed was changed into a mass of shale, sandstone and coarse conglomerate, containing much bituminous shale but no workable coal in its 18 meters of thickness. It would seem then that the Brouillages condition prevailed, at the outcrop, throughout the whole thickness of the deposit; that the petty lenses of sand and clay, observed in the Banc inférieur, are the last traces of detrital beds thickening toward the north and northeast.

Returning now to the westerly wall of the excavation, the Grande Couche, where last seen at the bottom of that wall, shows approximately 18 feet of coal above the Banc des Roseaux, the Banc des Chavais having disappeared. The dip, not easily determined, is not far from 20 degrees and at one time the coal was overlain by a grayish shale, of which a little remains in contact with the westerly wall. But the coal with most of this shale has been removed as by a thrust, and on the planed off surface there now rests unconformably a dark shale, wholly unlike that of the wall. The condition is shown in Plate XVI, figure 1, where the plane of contact and the overlying shales are sufficiently distinct, although as the exposure was in shadow, the details are somewhat obscure. Before considering this matter further, the features of the westerly wall, as exhibited in Plate XVI, figure 2, must be considered.

The reader will remember that in the Saint-Edmond a sandstone group was seen, which thinned westwardly and disappeared near the head of Forêt, so that the basal sandstone of the Grès Noirs, belonging above the top of the Saint-Edmond wall, is present in that of Forêt at not more than 80 feet above the Grande Couche. This interval remains practically unchanged along the outcrop into l'Espérance, a distance as great as the whole length of Forêt. At the entrance to l'Espérance, the basal sandstone of the Grès Noirs is soft, by no means coarse and directly overlying a thin bed of coal. It is, as in Forêt, an irregular deposit, with streaks and pockets of coal. The shales below the little coal bed to within 25 feet of the Grande Couche are more or less sandy, light gray and with layers of soft white sandstone, which are distinct along the wall and some of them appear in the photograph.

The little coal bed about 70 feet above the main coal at the stairway descends irregularly along the wall for about two thirds of the distance and

[1] Commentry, p. 241.

then plunges abruptly to within eight feet of the Grande Couche, where the exposure ends. The two coals are said to unite at only a few feet beyond. Beginning at the stairway with a thickness of only two inches, this coal soon increases to a double bed, two or more feet thick, but thins again to barely one foot before reaching the Grande Couche. These variations are shown in the photograph. The interval between the coals, as measured on the face of the wall, without regard to dip, decreases from 70 feet to zero within 300 feet. This is not a case of erosion; the thin white bands on the wall converge through disappearance of the intervening shales until almost in contact, and they, too, disappear where the little bed makes its abrupt plunge.

Meanwhile the sandstone at the base of the Grès Noirs, overlying this coal bed, thickens until at the southerly end of the wall, it becomes the striking feature and it is said to rest directly on the Grande Couche at a few feet beyond the end of the exposure.

Ascending the stairway at this end of the excavation, one finds, as shown in Plate XVII, figure 1, first the very light gray sandstone, not coarse, soft and holding many streaks or better irregular fragments of coal, some of which are several feet long and more than a foot thick. These coal patches are in no sense petty beds and are without definite form; some fade away at each end in a bunch of filaments; some terminate abruptly at both ends, while many are blunt at one end, broken up at the other. Above the sandstone is a mass of dark, almost black shale, 10 to 30 feet thick, loaded with irregular sheets of coal and containing bodies of sandstone resembling that below. At some exposures this deposit might be described as coal with much shale, at others as shale with much coal. Its coal is good, similar to that from the Grande Couche; it occurs in streaks one half inch to several inches thick and frequently several feet long; some of the thicker streaks show partings; and the amount of coal is sufficient to justify mining,— the foreign matters being removed by washing. It is difficult to give a proper conception of the amount of coal or of the manner of its occurrence. The conditions are wholly unlike anything which the writer has seen elsewhere. There is no coal bed, there is only a commingling of shale and coal. Occasionally, there is passage from one to the other, but that is exceptional; the coal and shale are distinct. The conditions throughout suggest that here one is viewing the ruins of a coal bed, which had been removed from its place and redeposited with its associated shale. Above this black shale is a moderately coarse sandstone, weathering yellowish and apparently containing no coal. These two sandstones with the intervening shales may be taken as representing the Grès Noirs group of Fayol.

Returning now to the lower level one finds himself on the basal sandstone of the Grès Noirs at the foot of the stairway; but within a few steps

along the southerly wall, he reaches the dull dark shales, already referred to as resting unconformably on the Grande Couche. They dip at 25 degrees, but whether or not they are conformable to the gray sandstone here could not be determined satisfactorily, as the bottom of that deposit seems to be very irregular.

The condition is perplexing. These shales bear no resemblance in color or texture to those underlying the Grès Noirs on the long westerly wall; there is no evidence along that wall that any disturbance took place just prior to the deposit or during the deposit of the gray sandstone, for the little coal rider of the Grande Couche is continuous under the sandstone. Yet just east from that wall, the Grande Couche and its overlying gray shale have been cut off and the dark shales, which clearly underlie the Grès Noirs, rest on the edge of the coal with different rate of dip, though in the same direction.

In the southerly wall, these dark shales, where first seen, have a dip of 25 degrees; within a few feet, they rest unconformably on similar shales with at first 15, then 20 degrees dip — the relations are shown in Plate XVII, figure 2. These seem to suggest a thrust; one is here at several feet about above the unconformity shown in Plate XVI, figure 2, which is distant only a few yards and the inclination of the planes is not the same.

Just here, however, one finds an abrupt change in the southerly wall. The dark shales suddenly become crumpled for a space 10 or 12 feet wide at the top of the wall but tapering downward so as to be insignificant within 20 feet; at once they are succeeded by a wholly different rock, occupying a trough in the shales. This is the phenomenon termed by Fayol, the Glissement de l'Espérance, and the features appear in Plate XVIII, figure 1. The space of plicated shale is not included. The easterly side of the trough is covered with vegetation and débris so that it could not be determined whether or not the Banc des Brouillages is involved. The dark shales underneath this rock-filled trough are partly covered by débris from the soft rocks above; but enough was seen to make clear that they are not crumpled. Coal seems to be in place at the foot of the wall, but its relations to the shales, two feet above, could not be ascertained; nor could the apparent thrust shown in Plate XVII, figure 2, be traced with certainty underneath the trough.

The material filling this trough bears no resemblance to anything seen elsewhere within the area of les Pégauds. It consists largely of light colored more or less feldspathic sandstone, with some light colored shales along with some bituminous shale and a large fragment of coal. All of the beds are closely folded and the coal fragment, as shown in the photograph, is crumpled into a double-ended hook.

Tranchée de Longeroux.

Leaving the Tranchée de l'Espérance by the stairway at this end, one passes over the whole of the Grès Noirs group and, following the alluvial cover, reaches the even more imposing Tranchée de Longeroux within a few rods. There the exposures are almost complete and reveal conditions much more complicated than those of l'Espérance. The yellow sandstone is at the top of the wall as one enters the trench and at 65 feet lower on the westerly side are two openings in the black shale. Half-way down to the latter and on the first bench, one is at the western border of the Glissement de l'Espérance, where the trough certainly seems to extend upwards into the yellow sandstone, but the contact is not shown. At the end of this platform, one reaches the basal sandstone of the Grès Noirs, which is divided by the stairway. There the sandstone has been pushed into a recumbent fold involving also the black shales, which are well exposed alongside in the wall. The photographs here are unfortunately on the same film, as the writer neglected to bring a fresh film into place. But the fold in the shales is recognizable in Plate XVIII, figure 2, being on the right side of the picture; its place is at the left above the stairway. The fold in the sandstone is obscured in the photograph.

At a few steps from the spot where this view was obtained, the contact between the gray sandstone and the dark shales is shown and they appear to be conformable. The shales are dark gray to lead-gray, fine-grained, tend to be flaggy and contain many excellent impressions of plants. They are sharply folded and the surfaces of the flaggy layers are often slickensided. The black shales of the Grès Noirs very frequently exhibit similar slickensiding. The polishing in both shales is such as one could expect to find in materials already hard. At times it is as marked as that observed in Ordovician shales within the Cumberland valley of Pennsylvania.

At a short distance from this exposure there are two openings in the black shales, which contain so much coal that, at 50 feet away, they resemble a bed of solid coal. The yellow sandstone is shown at top of the wall in an exposure, about 150 feet long, where it rests with irregular base on the black shales; it is cross-bedded but in thick layers, not in laminæ. Plate XIX, figure 1, shows that this crossbedding is not shared by the underlying shales. Whether or not the structure is original or secondary could not be determined; the underlying shales are much folded. Just beyond the opening at the left of the picture, a wedge of sandstone begins which increases to the end of the trench, where it is 12 feet thick; it is light gray and bears close resemblance to the basal sandstone of the group.

Descending to the bottom of the trench, where the Grande Couche is exposed, one finds the gray sandstone of the Grès Noirs more than 20 feet thick, containing a thin irregular lentil of coal and coming down to within 10 feet of the Grande Couche. A deep pit at a few rods south from this place shows a face of about 30 feet of coal, with the bottom not reached. Here the gray sandstone is almost in contact with the coal bed.

The Grande Couche has been subjected to pressure severe enough to break it into great wedges and a shale belonging above the coal was involved in the disturbance. Plate XIX, figure 2, was taken obliquely, so as to embrace some other features and it does not give the details of structure in the coal as sharply as is desirable. An attempt is made in Figure 2 to indicate some features less sharply shown or concealed in the view. There are three lines of fracture; one inverted wedge projects above the general surface of the bed; the recumbent wedge at the right has had an irregular under

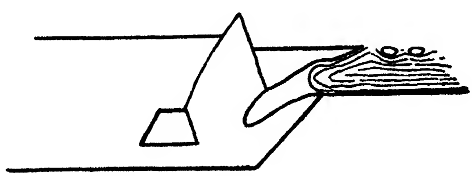


FIGURE 2. THE GRANDE COUCHE IN TRANCHÉE DE LONGEROUX

surface and it breaks up near the apex, so that two separated fragments are in the shale beyond. This shale is closely folded on itself — a detail not fully shown in the photograph — and this fold involves the coal also, for a prong of crushed coal, shown indistinctly in the view, passes down into the bed. The relation of the overlying dark shales is shown distinctly; they do not share in the disturbance which affected the coal and its accompanying shale. The fold in the bottom sandstone of the Grès Noirs is shown in the upper part of the photograph, below the tree.

The manner in which this coal is broken, the sharpness of the lines bounding the wedges, the acuteness of the projecting apex and the crushed fragments within the loop leave no room for doubt that the disturbance, whatever its nature may have been, occurred not while the vegetable matter was in pulpy condition but after it had been consolidated — after it had been converted into a bed of coal. The shales involved in this crush are unlike those between the coal and the Grès Noirs, which are the dark shales and, along this outcrop, are undisturbed, though they show irregularities along the dip — not related to those of the coal as exposed here.

The Banc des Brouillages, or Banc du mur, is well exposed as it forms the easterly wall in a great part of the excavation.

The dark shales, less than 10 feet thick near the deep pit, thicken very rapidly toward the north and, as shown in the photograph, form the notable feature along the central line of the trench. They contain thin bands of whitish sandy rock which contrast sharply with the other beds and serve, by converging toward the coal exposure, to show that the rapid southward thinning of the mass is not due to a squeeze, but that the conditions are similar to those seen in l'Espérance. At about 100 feet from the deep pit and on the platform at the right side of the photograph, a trial pit has been sunk, reaching the Banc inférieur, which is shown to the thickness of six or seven feet. The dip is 40 degrees and the coal is cut off sharply; on this leveled edge, the dark shales rest, dipping at 55 degrees in the same direction, but they are apparently conformable to the Banc des Brouillages in the easterly wall.

The explanation of these relations, as of those in l'Espérance, would be sought for at once in a thrust. But in that case the Banc des Brouillages should be involved, the part of that division above the plane of non-conformity should rest on higher portions of the Grande Couche and one would be justified in expecting to find at least some traces of those higher portions in other exposures, between the Brouillages and the dark shales. But the miners know of no coal underlying the Brouillages at this place; that part of the Grande Couche is well shown at few yards away, several feet below the bottom of the trial pit and at least 12 feet below the plane of non-conformity in that pit; thence it is absolutely continuous up the easterly wall to the top of the trench. At barely 10 yards away in the opposite direction and at less than 20 feet above the top of the trial pit, the dark shales and the Brouillages are in contact and they are conformable. It is certain that the agent which carried away the Banc inférieur and higher portions here did not affect the Brouillages to any appreciable extent.

A long extension of the trench begins at somewhat more than 20 feet above the level platform shown in the photograph and continues toward l'Espérance. Along the easterly side, the dark shales having crossed the higher portions of the Grande Couche, they rest conformably against the steeply dipping Brouillages or lower part of the Grande Couche, which forms the easterly wall. Following this extension, one at length finds the upper portions of the coal bed in the floor and at the end, at the foot of the northerly wall, an exposure shows the coal again cut off abruptly, with the dark shales resting unconformably upon its edge. The shales above the plane of fault are the dark shales and the illustration shows their flaggy structure; the shales conformable to the coal, below the plane show very little tendency to that structure and are evidently of different type. The conditions are exhibited in Plate XX, figure 1.

The coal here is apparently the upper portion of the bed; but the plane of fault is at least 25 feet higher than in the trial pit, so that it had a somewhat rapid fall southwardly. That the plane declines in that direction is very clear, for the coal soon drops below the floor of the extension and thence to its beginning one walks only on the dark shales. The relation of this exposure to that on the other side of the wall in l'Espérance was not ascertained, but judging from the interval to the bottom of the Glissement above, the exposure in l'Espérance is probably a little higher.

Returning now to the beginning of the extension, if one climb to an opening in the Brouillages, about 25 feet, and look across and along this portion of the trench, he finds the l'Espérance convergence repeated but in different rocks. There, the light gray shales or fine sands, derived from the Montassiégé side, gradually disappear and the Grès Noirs gray sandstone comes down to the Grande Couche; here, several hundreds of meters away on the outcrop, a similar change takes place, but in the fine-grained dark shales derived from the Longeroux region. It is seen partly in Plate XIX, figure 2. As the shales decrease, the white lines converge in some instances, fade out in others, until, instead of 75 or 80 feet, one finds not more than six feet between the Grès Noirs and the jagged top of the Grande Couche. The top of the coal bed at this place, the deep pit, is below the plane of faulting. The conditions are such that in any ordinary locality, one would conclude at once that here is the thinning of deposits against a shore line.

The Glissement de l'Espérance is well shown in the northerly wall of Longeroux. The whole of the upper part was laid bare at this end, but the exposure is no longer very distinct on the easterly side, as the débris has been covered largely by vegetation. The width at the top is estimated at 450 feet — it may be somewhat more. Perhaps one third, above, has been removed in making the upper platform on the west side, but the whole mass on the easterly side, so far as spared by erosion, remains and is sufficiently exposed to give a fair conception of the relations. The features of the westerly side are shown in Plate XX, figure 2.

The rocks occupying the trough are in marked contrast with the dark shales alongside; they are very light in color, mostly sandstones, with at least one bed holding lines of pebbles which, as seen 100 feet away, are from one to three inches long. The beds within the trough are very sharply flexed on the westerly side, but the bending is less beyond the axis of the syncline, and on the easterly side the beds are quite regular with comparatively gentle westerly dip. The contact on this side is not shown fully, as the wall is less abrupt; débris has accumulated and some of the features are obscure. But the deposit reaches to or very nearly to the Banc des Brouillages, which is well shown at 25 feet away with dip of from 45 to 55 degrees toward the

trough. It is clear that some of the light-colored beds terminate against the easterly wall of the trough and that the higher beds form a syncline with gentle dip on that side. Whatever the origin of the material may have been, the greater mass was deposited on the westerly side and whatever the cause of the folding may have been, the resistance was especially strong on that side. The only locality, outside of the trough, where rock of this type was seen, is at the extreme northwest corner of the basin; there, in a railroad cut, near the station of Chamblet-Néris one finds a precisely similar rock, holding lines of pebbles arranged as are those in Longeroux.

The bottom margin of the trough is well shown to beyond the middle, and the light colored rocks rest on the dark shales which are as little disturbed as are those in corresponding position within l'Espérance. But on the easterly side of the extension, the shales, resting conformably against the Brouillages, have, in many layers, slaty cleavage, the surfaces being divided into rhomboids and thoroughly polished. On the westerly side, these shales, as the photograph shows, are sharply flexed and one of the folds is broken, with an overthrust fault as the result. The gray sandstone and black shales of the Grès Noirs share in this disturbance, the folds appearing in Plate XVIII, figure 2 and Plate XIX, figure 2 being just beyond the limit at the left of this photograph.

A cross section is shown in a cliff between photographs, Plate XIX, figure 2, and Plate XIX, figure 2, where the dip is from 25 to 40 degrees. The noteworthy feature there is the complicated folding in some beds, shared to very limited degree by those adjoining. A faisceau of three beds, the middle one much lighter in color than the others, is seriously distorted, the middle one being closely folded on itself at one spot. As the wall is sheer, the beds cannot be examined and one may not be certain whether the distortion was due to a slide when the rocks were unconsolidated or to the more yielding nature of their materials, allowing them to receive a disproportionate share of the pressure during folding. The latter suggestion appears the more probable, as traces of the swelling are traceable in the adjoining beds.

It is deserving of note that though the disturbance sufficed to push the Grès Noirs into recumbent folds, to induce slaty cleavage and slickensided surfaces in the dark shales as well as in the black shales of the Grès Noirs, yet the coal in the latter is fat with long flame; and the same is true of the Grande Couche,[1] which, in all probability had already suffered severe disturbance.

In climbing out of Longeroux trench by the easterly wall, one is con-

[1] FAYOL: Commentry, p. 24.

stantly on the Banc des Brouillages, which exhibits the same features as in Forêt and l'Espérance; but some of the sandstone layers are coarser than any observed in those trenches and contain abundant remains of plants — chiefly fragments of stems with the cortex converted into coal. These rock layers are light colored in all of the trenches and are not bituminous; those which from a distance seem to be dark colored are found on closer examination to owe their color only to the presence of carbonized fragments, not to diffused bituminous matter; the mineral portion is as light in color as in the other layers.

Near the top, at the southerly end of this trench, one finds the Glissement once more, its upper portion being exposed in a recently opened quarry. At the northerly end of the trench it seems probable that the trough involved the highest sandstone of the Grès Noirs; but at this end the matter is placed beyond doubt, for the yellow sandstone forms the westerly wall of the trough, thus showing that the trough did not originate before the middle division of Commentry measures had been deposited completely. The Glissement rock is almost wholly sandstone with dip of not more than 15 degrees southeastwardly, but slightly more at the westerly wall. The yellow sandstone is hardly disturbed at the contact and is unaffected at 10 feet away. There is no exposure beyond the immediate vicinity of this quarry, but the topography southward is such that the Glissement sandstone must extend in that direction and that it reaches a higher level than at the quarry, so that there the wall of the trough must reach up into the shales which overlie the yellow sandstone.

As one ascends the stairway to the quarry, he sees a deep excavation on the easterly side, cutting into the course of an old stream, which dug a narrow valley, now filled with sand and gravel belonging to the recent deposit, covering this part of the Commentry basin to the depth of 10 to 20 feet.

Leaving the Longeroux trench at the quarry one reaches, at about one fourth of a mile, an opening into a still higher coal bed, whose relation to the other deposits could not be determined. The pit is, by barometer, 280 feet above the Grande Couche, but the direction is considerably off the strike and the irregularity of dip is such that no calculation of vertical distance can be made. The bed seems to be not less than 75 feet above the top of the Grès Noirs group. The coal is reported to vary between three and seven feet and it is associated with a clay shale, drab but weathering yellowish. This is the highest bed examined by the writer.

In following the road from this pit westwardly to the present mine, one finds no exposures; but along an old road, a little northward, a good exhibition of the yellow sandstone with southerly dip of 25 degrees, was seen

within five minutes walk from the shaft. Still nearer that mine is the abandoned Tranchée de Goutilloux, now almost filled with waste. There one can still see the upper portion of the Grès Noirs group, which, at one time, was fully exposed in the south wall. This is only a few rods south from the Tranchée de Saint-Edmond, in whose south wall the Grès Noirs are not reached.

The enormous trenches on the west side of the Pégauds area are utilized no longer for mining but as dumping grounds for waste from the shaft and washeries as well as from the great iron works in Commentry. The Grande Couche has been removed and the lower part of the well has fallen, so that for variations in the coal bed one must depend on descriptions given by Fayol. But the upper part of the southerly, becoming easterly wall still remains intact, exhibiting as clearly as ever the vagaries of deposit which that author has described with great detail. As the exposed conditions are not unlike those already observed, it is unnecessary to dwell upon them.

Grande Tranchée.

The Grande Tranchée is north from the mine, between it and the city of Commentry. It extends approximately east and west. Before abandonment it was 750 feet long by 200 feet deep, but it is now much shorter and less deep, as waste has been dumped at both ends and along the north side. The exposures along the south wall are thoroughly characteristic; local faultings, confined to two or three beds; disappearance of single beds or of petty faisceaux of beds; local crumplings and other phenomena already familiar are numerous. The sandstone overlying the Grande Couche in Saint-Edmond persists. This trench was connected by tunnel at the west with the tranchée de l'Ouest et du Pré-Gigot.

Tranchée de l'Ouest et du Pré-Gigot.

The trenches of l'Ouest and du Pré-Gigot were formerly separate, but now are continuous. The Grande Couche has been followed in the works from Saint-Edmond into l'Ouest, but one carried from Longeroux to this extraordinary excavation might well imagine that he is still at the Grès Noirs horizon.

The yellow sandstone is seen in many places at the top of the wall, overlying a gray sandstone, weathering less strongly yellow, which is quarried as building stone at the farther end of the trench. This rests on a great mass of shale and sandstone, which in turn rests on coals and shales, while at the bottom is a gray, irregular sandstone, with an indefinite coal deposit.

This lowest sandstone is shown on the northerly wall near the head of the trench where it is 17 feet thick. But as one advances into the trench, he finds the Brouillages structure prevailing on the northerly wall.

The complexity of deposits shown in the long almost sheer wall of these trenches far exceeds anything observed in the other trenches and is intimation that one is approaching the massive delta of the Montassiégé area. Here one sees in full detail all the changes which geologists elsewhere, depending on separated sections and records of borings, have expressed in diagrams but which they have never seen in place.

About half way in this trench, the yellow sandstone is separated by perhaps 70 feet of shale and sandstone from the highest coal-bearing shale below; but at about 300 feet farther the interval is barely half as much. Almost midway between these points, a group of beds, estimated at 40 feet, is folded, curled on itself and cut off abruptly, but the overlying beds are undisturbed. The sandstone at the bottom of the wall seems to be that observed in the Grande and Saint-Edmond trenches. Ordinarily it is regularly bedded, but occasionally it is cut out by downward extension of the overlying shales. At many places it swells below and cuts out the underlying shales. These projections below have no definite bedding and bear little resemblance to the main bed. They are often gnarled like burly wood; at times they consist of thick rudely concentric bands; while at others they are made up of folded layers. Here one can see all variations of the coal measure sandstones, in full day, showing the features of delta deposit as American geologists have conceived them.

The coal has been removed for a long distance and the almost continuous "fall" prevents study on the southeasterly side; but on the opposite side of the trench one finds along the great face a succession of coal, coaly shale and sandstone, recalling in some respects the Grès Noirs conditions of Longeroux but for the most part those of the Banc des Brouillages in the eastern trenches. The coal is more or less slaty, but in one layer, mined apparently for local use, it is very clean.

The shales associated with the coal afford ample evidence that they have endured severe pressure, such as accompanies distortion. All are at times much contorted, are flaky and polished as though they had been the soft material between harder beds, and had yielded so as to become pockety. The conditions are not unlike those observed in the Pocono coal beds within the faulted folds of southwestern Virginia.

Variations of the Grande Couche.

It remains now to describe the variations of the Grande Couche at the extremities of the outcrop as well as in the deeper parts of the workings

under cover, conditions not exhibited in the trenches; for these one must depend on Fayol's descriptions.

Near the village of Longeroux on the eastern side of the Pégauds area, the outcrop shows only a few inches of coal: The Grès Noirs and a higher bed, that of les Pourrats, are given off as the bed thickens and the intervals between them increase rapidly. The Grande Couche soon attains the thickness seen in the Longeroux trench; in l'Espérance, it is divided by the two partings, the Banc des Chavais above and the Banc des Roseaux below, of which the former disappears in Forêt while the latter continues into Saint-Edmond, where the bed becomes practically one, with a thickness of 10 to 12 meters. The Banc des Brouillages or Banc du mur, not included in the thickness given, is continuous from the trench of Longeroux to the east end of Saint-Edmond, beyond which the writer did not recognize it with certainty.

This much one may gather from the trenches as they now exist; for the rest he must turn to Fayol.

Followed westwardly, the Grande Couche begins to divide in the Grande Tranchée. A small bed, known farther west as the Sixth, is seen three meters below the Grande Couche at the east end of that trench, but the interval increases to 23 meters at the west end.[1] In the Tranchée de l'Ouest, the bed continues to divide, and before the end of that trench has been reached there are six beds, so that the single bed near the village of Longeroux had been divided into eight beds, distributed in a vertical section of more than 200 [2] meters. In the region of Saint-Augustin, five of the six branches have been followed to their disappearance along the strike. There is gradual thinning of the coal and at last a rapid disappearance in the sandstone which there forms the mur of the Grande Couche.[3] The sandy wedges entering the bed in the Grande and Ouest trenches increase and the coal decreases.

Followed down the dip, the Grande Couche gradually becomes thinner and at length disappears toward the depth of 350 meters. In one pit, the coal becomes only two to three meters thick at 225 meters, where it is of good quality and without intercalation; but at 36 meters farther, there remain only a few films of coal, and the Grande Couche is represented by a dozen streaks of carbonaceous shale, separated by shales including a thin sandstone.[4]

To sum up: The Grande Couche, outcropping in the form of a very

[1] FAYOL: Commentry, p. 265.
[2] FAYOL: Commentry, p. 24.
[3] FAYOL: Commentry, pp. 282–283.
[4] FAYOL: Commentry, pp. 24, 280.

open "C," has its greatest thickness along the northern and northeastern border; it thins out to nothing on the eastern side, but on the western side it divides into several branches, each of which fades away as the sandstone wedges thicken, until this sandstone becomes a continuous section. Down the dip, the bed gradually decreases and ends in several thin beds of carbonaceous shale.

History of the Commentry Basin.

Such are the facts observed within that part of the Pégauds area which contains the Grande Couche and its subdivisions. It remains to consider the succession of events in the area, and this must be done with a degree of detail, justified, not by any importance possessed by the area itself, but by the importance of generalizations which have been based on its structure.[1]

The deposits in the Commentry basin have been divided into

Lower, consisting almost wholly of rather coarse materials, but containing some unimportant lentils of anthracite;

Middle, consisting chiefly of fine materials and including the great coal beds;

Upper, containing practically no coal and consisting of rocks more or less coarse.

Only indirect reference has been made to rocks of the Lower division, as they seemed to have little bearing upon the problems with which the writer's study is concerned; but it is well to note the conditions as described by Fayol.

The total thickness of beds between the Grande Couche and the bottom is 800 meters at the eastern extremity and 500 meters back from the Tranchée de Forêt. These thicknesses were ascertained by surface measurements, as no boring to the bottom rock has been made under the coal bed and nothing is known respecting conditions midway in the Pégauds. These Lower beds have little coal, but they yield ample evidence that, before they were deposited, vegetation had gained hold on the surrounding country. For the most part, the detritus is coarse and shale is of rare occurrence. One singular deposit, the Banc de Sainte-Aline, only 15 meters below the Grande Couche, has a curved outcrop similar to that of the coal bed and is a mass of mica schist, granulite and granite fragments, many of them very large, mostly angular and cemented by smaller fragments of the same rocks. Its extreme thickness, 60 meters, is on the northerly and northeasterly border

[1] Some important conclusions presented in Fayol's work, as well as ingenious suggestions offered by several later authors cannot be considered here. They will be discussed in a monograph upon the formation of coal beds which the writer has in preparation.

and the mass decreases southwardly until it disappears more than half way from the southern border. In the earlier days it was supposed to be a primitive rock, but Fayol's studies disclosed its true character. Its outcrop is five kilometers long and the content is estimated at 125,000,000 cubic meters.[1] The writer made only cursory examination of it near Chavais.

The map of the Commentry basin, Figure 1, shows approximately the extent of the several zones or areas of deposit. By careful study of fragments, Fayol was enabled to determine the source of materials found in each, to reconstruct the drainage system and to follow in detail the gradual filling of the basin. Figure 3 shows his conception of the drainage area.

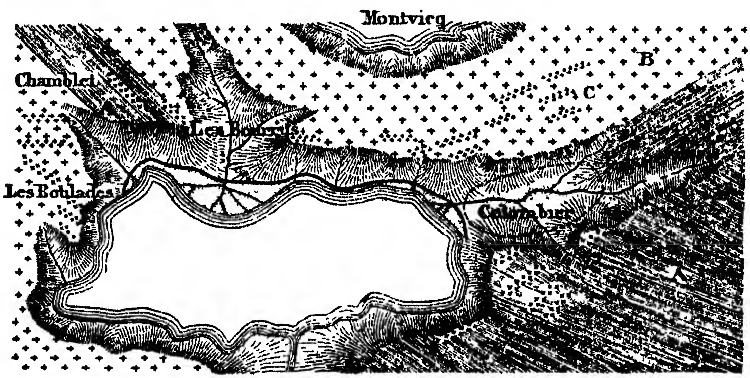


FIGURE 3 THE DRAINAGE AREA OF LAKE COMMENTRY. A, GNEISS, B, GRANITE

Reference has been made already to de Launay's recognition of a double trough extending northeastwardly from near Montluçon toward Moulins, 60 kilometers away, the divisions being separated by a granite crest. The western division is limited at the northwest by a fault of 200 meters, which is distinct in the northerly portion but not in the Commentry region; there, however, the western border of the basin evidently coincides in direction with the fault, and the coal measures there as well as at the south, are in contact with the granite as appears from de Launay's map. The syncline was divided by westward movement of the granite into several petty basins which were afterwards filled by lakes.[2]

Fayol's conception is that of a lake, nine kilometers long, three kilometers wide and 800 meters deep, surrounded by steep mountains on almost all sides. Les Bourrus at the north and Colombier at the east were the valleys whence came the chief affluents; some narrower valleys, Chamblet

[1] Fayol: Commentry, pp. 96–102.
[2] De Launay, L.: Réunion etc., pp. 98–100

and les Boulades, were at the west, while the north and west borders were furrowed by ravines. The Bourrus delta (Montassiégé area) advanced most rapidly and reached the southern border of the lake before that of Colombier (Longeroux area) had advanced more than one kilometer, and the lake was divided into two lakelets, les Pégauds at the east and les Ferrières at the west; meanwhile, the Bourrus delta had united on the northern border with that of the Colombier at the east and with that of the Chamblet at the west, so that, within the lakelet areas, one finds a commingling of materials from both sides. The coarser detritus was deposited in the deltas, but the finer materials passed beyond and were deposited in the lakelets, so that, in the latter, coarse beds are rare, at least in the middle division of the measures. These finer materials, both mineral and vegetable, were deposited in accordance with their specific gravity, the distribution being that observed in river deltas as well as in deltas formed experimentally. The area of Pégauds, receiving contributions from both the Bourrus and the Colombier, has a much greater amount of mineral and vegetable matter than has that of les Ferrières, which received only from the Bourrus and some smaller affluents.

When the lake had been filled in great part by the transported matter, when the Grande Couche had been completed, the Grès Noirs and Pourrats coal beds were formed. They are irregular, lenticular, impure and give evidence of having been deposited in shallow water, troubled by frequent displacement of the mouths of streams. After the formation of the Pourrats bed, no vegetable mass accumulated. At last the lake was filled and streams began their work of erosion. There are no horizontal beds, such as one would expect to find closing the series in a delta-filled lake — perhaps there was none at any time. The absence of these beds is due to later as well as to contemporaneous erosion, the latter caused by constant deepening of the outlet at the south, amounting in all to about 100 meters.

The Bourdesoulles area received its coarse materials from les Boulades, a gorge with steep walls; the Chamblet stream flowed through a narrow valley, also with steep walls, but having a drainage area of five by 2.2 kilometers and resembling the valleys now seen in the region; the Bourrus stream was about 15 to 20 kilometers long, with wider drainage area than that of Chamblet and was torrential throughout; the extent of the Colombier area is not given, but if one may judge from the map, it is supposed to have been no smaller than that of the Bourrus and the stream, though torrential, was less rapid than the Bourrus. Apparently no débris entered from the south.[1]

[1] Fayol. Commentry, pp. 63–93. Réunion etc., pp. 20–21.

The abruptness of the valleys and the torrential character of the streams as conceived by Fayol appear from his explanation of the origin of the Banc de Sainte-Aline, which is about 50 feet below the Grande Couche and still underlies it at a depth of 300 meters. Its content is estimated at 125,000,000 cubic meters. It appears abruptly and disappears with equal abruptness, being followed by comparatively fine material and that by the coal. Its greatest thickness is at the north and northeast and its fragments prove that it was derived from the lower part of the Colombier area. Fayol's explanation of its origin is

> A fall of part of the mountain occurred in the region of Merlerie; the valley was obstructed; the waters accumulated and rose behind this barrier; then, all at once, breaking their dam, they carried out the materials as far as to the alluvial plain and to the lake.[1]

That a slide as great as this is not impossible is proved by reference to some of vast extent in the Alps and elsewhere. But the matter in hand does not concern the mass of rock, it has to do only with the mode of transportation. To the writer, this part of the problem appears much more difficult than Fayol seems to think it and the explanation given would only increase the difficulty. The valley of the Colombier at this time could not have been more than a kilometer wide, for its delta extended only a kilometer into the lake and the valley was evidently seven or eight kilometers long. If that valley were a kilometer wide, the slidden mass would have to cross it, have a length of three kilometers and a height of 40 meters. Such a landslide is quite possible in some types of rock, for that in the valley of the Adige near Rovereto is greater, and that near Lake Lucerne, mentioned by Fayol, is comparable to it. It is not altogether easy to conceive of such a landslide in the mica schists of the Colombier region, but certainly it is not impossible.

A mass so great as this would be an effective dam and the water would be ponded behind it. But here one has to consider not a vast river but a petty stream, merely a brook, for the Colombier was not much more than five miles long and its fall must have been quite rapid, as, for most of the length, the brook was in the youthful stage. The pond behind the dam could not be much more than a mile long and it would not form at once. One has difficulty in understanding how even a cloudburst at the head of the brook could gain such impetus as to tear away a mass one kilometer wide and three kilometers long. The pond was already there, held back by the dam; only the upper part of the slide would be torn away by the flood. The normal process would be for the water to cut a channel in the mass, which

---

[1] Commentry, p. 100.

would drain the pond gradually and the whole might be removed by a succession of floods during a long period of time. This method of cutting through landslides is very familiar to American geologists, and it must be equally familiar to geologists in Europe, for illustrations are numerous in the valley of the Adige and are even better in the valley of the Rhone, where vast cones of dejection, which cross the valley, have compelled that mighty river to find its way through the thinner part of the mass near the opposite wall. These cones have been only trenched by the torrential streams.

The writer made no study of this deposit and he can offer no explanation to account for its presence.

The tendency to explain conditions by almost cataclysmic agencies appears equally in the consideration of the Banc des Chavais. This parting in the Grande Couche extends along the outcrop from midway in l'Espérance to almost midway in Forêt, barely half a mile. It is a lentil, nine or ten feet thick at most; it is fine-grained at top and bottom, very coarse in the middle; above and below as well as laterally it passes into coal; and its longer axis is in direction of the outcrop. This is supposed to be the product of a great flood, which tore away the surface of the alluvial plain. The coarse material was dropped to form the banc, but only a small part of the vegetable matter went down with it; the greater part remained suspended being lighter, and subsided slowly afterwards on top of the gross materials, so making part of the Banc supérieur.[1]

There is difficulty here also. The geographical distribution of the Banc des Chavais shows that it was derived from the Colombier region, so that it must have been transported by that stream. The fragments of the rock are waterworn, not angular, and are supposed to be those left behind on the alluvial plain by the Sainte-Aline débâcle. If the débâcle had left fragments stranded on that plain, they could not become waterworn unless the plain were covered by moving water — in which case it could not support vegetation so abundant as to produce the large amount of coal found in the Banc des Chavais. Besides, it is supposed that the Banc de Sainte-Aline had swept across this plain only a short time before with its vast mass of sand and huge angular blocks, which could not fail to plough off the surface after an extraordinary fashion. It is better to seek the explanation in less violent action, for one must remember that transition from the Banc intermédiaire to the Banc des Chavais is very gradual at most exposures.

This matter leads at once to consideration of the mode in which the Grande Couche was formed — and this is a matter of chief importance, which must be considered in detail.

[1] Fayol: Commentry, pp. 103, 104.

Origin of the Grande Couche.

Fayol's thesis respecting the origin of coal beds is this:

The beds of coal were formed after the same manner as the beds of shale and sandstone; the plant materials carried by the streams along with clay, sand and pebbles, were mingled sometimes in midst of the mineral sediments, sometimes heaped in beds or masses more or less pure. Just as the clay, carried simultaneously with the coarser elements, is fixed partly in midst of those elements and at the same time forms some distinct beds. In like manner, plant débris, which, from the standpoint of sedimentation, is equivalent to fine mineral particles, remains partly in midst of the coarser sediments and is deposited especially along with the clay or in its vicinity.[1]

Fayol presents a careful calculation aiming to show that the drainage area of the lake was sufficient not only to supply all vegetable matter needed to form the bed, but also to supply it in a very short time. He estimates that to complete the Lower measures, a period of 13,000 years may have been necessary, as the streams were small and the advance of the deltas very slow; but with lengthening of the streams the advance was more rapid, so that deposition of the Middle and Upper measures required only 4,000 years. One hundred seventy centuries sufficed for accumulation of the whole deposit, including the coal beds.

The surface for vegetation was co-extensive with the drainage area. At the beginning, this was confined to some hectares of abrupt shore, as the mountains rose to perhaps 1,000 meters above tide [or about 1,200 feet above the lake surface]; but when the Grande Couche began to form, the emerged surface of the deltas had an area of 1,800 hectares [about seven square miles] and the streams gathered water from 10,000 hectares [barely 40 square miles]. At the end of deposition, the alluvial plain was 3,100 hectares [about 12 square miles] and the whole drainage area was 16,000 hectares [nearly 63 square miles]. On the average, the available area for vegetation during the earlier period was about 2,000 hectares and for the later about 15,000 hectares.

The amount of coal from a *Cordaites* stem has been determined. Reasoning from this, Fayol shows that a forest of *Cordaites* trees, each individual having a space of 10 meters square and attaining full growth in 50 years, would yield during each century a layer of coal, 60 millimeters thick over the whole area. In addition, the herbaceous plants and shrubs, such as ferns, lepidodendra, calamodendra, forming the underbrush, would furnish as much coal as the trees per unit of surface. But the amount of coal in the

[1] Commentry, p. 17.

deposit represents only a bed of four to eight millimeters per century over the whole surface of vegetation, or one tenth of the coal material produced, so that nine tenths of the vegetation was decomposed in the air.

This difference between the amount produced and the amount preserved leads him to suggest that possibly the deltas advanced twice as rapidly or that the vegetation was only half as luxuriant as imagined. In either case, the coal material produced would be five times as much as has been preserved in the deposits. The brevity of time required by this deposit is regarded as one of its chief commendations, for the period assigned to complete formation of the measures is only 170 centuries, whereas the hypothesis of accumulation from growth *in situ* would require 800 centuries for formation of the coal alone.[1]

The writer cannot see his way clear to acceptance of this explanation.

One must not forget that the events under consideration occurred, not in a great inland sea like Niagara or Erie, but in a little lake, barely six miles long and two miles wide; that when accumulation of the Grande Couche began, the lake had been almost divided by the Bourrus delta, so that there were two ponds, each of which was limited still further by a fringe of new land from the other shores; and that from all sides there entered torrential streams, emerging from narrow valleys a kilometer to some hundreds of meters from the water's edge. The conditions of the larger pond, that of les Pégauds, are alone to be considered here, as that is the one on which chief stress has been laid and to which the writer's observations were confined. When the Grande Couche was begun, this pond had an area of possibly 2,500 acres and was connected with that of les Ferrières by a strip of water along the southern border of the basin. What then must have been the conditions on the delta plain and on the highlands?

The delta surface is referred to as the "alluvial plain"; but that term must be used in this connection with important limitations. When deltas are spoken of, one is apt to think of the level deposits at the mouth of the Nile, Indus or Mississippi, composed of fine materials brought down by streams, thousands of miles long and with gentle fall. Such deltas are liable to overflows, but the floods are not violent; in the last stages of subsidence, the floods merely undercut the stream banks, the shores fall and throw into the stream whatever may be above. But that was not the condition on the deltas of Lake Commentry. They were made by torrential streams, which deposited the coarse material just beyond their emergence from the highland, while the finer materials were carried to the water basin beyond. One must think of the delta surface as resembling that of dejec-

[1] FAYOL: Commentry, pp. 322–324, 330.

tion cones such as are seen at the mouths of torrential streams entering the valley of the Rhone or that of the Adige, where one sees a mass of fragments from sand to great blocks. But that comparison does not suffice, for much of the Commentry plain had been deposited in water and little of the finer stuff was dropped at the shore. One must picture to himself a narrow, irregularly hummocky surface, covered by coarse gravels and blocks of rock, exposed to danger of devastation by rapid floods.

The rocks surrounding the basin are all "primitive," — granites at the north, west and south, except a very narrow strip of mica schist at the north, while gneiss and mica schist are at the east and southeast. The basin owed its origin to orogenic movements, and filling began as soon as the topography was defined. It was a region of "abundant but not extraordinary"[1] rain; the surface was irregular, the rocks refractory and the streams were torrential. Everything was unfavorable to rapid formation of a soil cover, but everything was favorable to rapid removal of loose materials. The streams, being torrential, were occupied in corrading their beds and the valleys were necessarily narrow with abrupt walls. Here and there along the course, little parks were formed above obstructions offered by more resistant layers or by rock falls from the sides; but with removal of the obstruction or with opening of a passage through it, the stream quickly cut down its way and freed the surface of the park from danger of overflow. The conditions were not those of broad Alpine valleys, remodeled by glacial action, but such as one finds in the valley of the Viége descending from Zermatt with its close tributary canyons; in the Royal Gorge of the Arkansas and the valley of the upper Eagle in Colorado; or in the area surrounding the Yosemite.

The dense vegetation imagined by Fayol would be impossible in the drainage area of Lake Commentry. It demands a growth of trees as dense as that of a forest in the temperate zone with an undergrowth like that of a tropical jungle. A region, such as that surrounding Commentry and les Pégauds could have only a sparse growth of trees and the undergrowth would be insignificant.

The estimate is of the whole amount of woody matter produced continually on the drainage area and this supposed possible product is shown to be far in excess of the quantity required to make the coal. But granting the possibility of a growth so dense, the query at once suggests itself: How could the vegetation be continuous and, at the same time, be carried to the lake?

If the plants grew in the beds of streams or in clefts within reach of

[1] Fayol: Commentry, p. 330.

floods, they would be torn out by high water and carried down; but even then the larger plants would be swept out with coarse materials to be inclosed in the sandstones — as Fayol properly emphasizes in another connection. On the other hand, if the vegetation had been as dense as imagined, it would have resisted even more than ordinary rains on the upper reaches which made up the 40 square miles of drainage area. If the rain had been so terrific as to tear off the trees and sweep away the undergrowth, it would have removed the soil also and ages would pass before return of conditions favoring a dense growth.

The hypothesis is not consistent within itself. The mode in which the measures accumulated necessitates a surface incapable of supporting dense vegetation; but the supposed vegetation was so dense, that it would have been its protection against any but the most terrific series of cloudbursts; in case of such a débâcle, only a small part of the vegetable matter could be deposited as a coal bed, for the trees, making one half of the whole amount, would be loaded by materials around their roots, would be snags in the mass of detritus and would be buried in the sands; even the twigs and underbrush would be entangled in the mass, for in the short course of the torrent there could be no sorting action and all would be dropped when the flood's velocity was checked on the comparatively broad delta surface. Only the very finest material, mineral or vegetable could find its way to the bottom of the basin — yet it is certain that the trunks of trees make up a very considerable part of the Grande Couche.[1]

It is well to remember that the supposed subsidence of tree stems in the basin is hardly in accord with observed conditions. Such stems as might escape entombment on the delta plain would shoot down with great velocity into the Pégauds basin, where at most they would be little more than a mile from the outlet toward which the surface water would be hastening. Those who are familiar with the western rivers of the United States know well that logs and stems float for hundreds of miles and remain long before decaying. It is more than probable that most of the tree trunks brought down by the torrential streams would find their way along with much of the finer materials to the outlet and that only a minute proportion of the vegetable matter would be deposited within the basin of les Pégauds. The existence of this outlet appears to be ignored by the hypothesis under consideration.

When one considers the enormous mass of the Grande Couche, certainly not less than 30,000,000 cubic meters, he must recognize that it could hardly be derived, except during an inconceivably long period, from such vegetable matter as could be washed in from 20 square miles,— two thirds of the rocky

[1] FAYOL: Commentry, pp. 144, 145, 152.

or rock-covered drainage area — for it must be remembered that during the same period another great bed, smaller in area but attaining an extreme thickness of more than 60 feet, was formed in the little lakelet of les Ferrières and that it is supposed to have come from the Bourrus with small contributions from Chamblet and Les Boulades. The source of the material must be sought elsewhere.

The form and variations of the Grande Couche, even if there were nothing more, would seem to leave little room for doubt that the bed represents plants which grew where the coal now is. But evidence from peculiarities of the bed is reinforced by the apparent impossibility of deriving the material from any other source. The history appears to be as follows:

The streams entering the Pégauds area had cut down their channels, so that for two or more miles from the water they flowed with gentle fall and carried comparatively little mineral matter into the basin, except in times of unusual flood. The filling of the lake had come to a halt. The Bourrus delta, composed largely of coarse material from the granites, had been pushed nearly to the southern border, while that of the Colombier, composed of less coarse material from more readily yielding rocks, had less of emerged area, the most of its load having been carried into the Pégauds pond. The plain, covered mostly by cones of dejection, was separated from the water by a low ill-drained beach on which a marsh originated. The principal outlets of the Bourrus and Colombier flowed on each side behind this curved beach and entered the pond near the present southward termination of the coal's outcrop. Rivulets entered from the north, carrying, except at rare intervals, only fine silt.

The marsh growth consisted of *Cordaites* trees, which form an important constituent of the coal, with a dense growth of ferns, lepidodendra and other plants. Within the little area inclosed by the curved shore, detrital deposits were insignificant, being for the most part only such material as eddied back into the stiller water from the stream-mouths at the sides; and the shoreline's advance would be due chiefly to invasion of the shallow water by growth of the swamp itself. The accumulation of swamp material on the strand would be enormous, but the thickness would decrease abruptly toward the water.

A similar condition existed in the smaller pond of les Ferrières, where, according to Fayol, the formation of the great bed, 20 meters thick, was synchronous with that of the Grande Couche.

The forking or branching of the Grande Couche on the western border was due to floods in the Bourrus, which broke across the plain and washed the sands into the swamp. The conflict between flood and swamp is well shown on that side, where the several branches of the Grande Couche have

been followed to their disappearance. On the east side, the more peaceful Colombier rarely broke across the plain, and the marsh followed with little interruption the slowly extending strand southward. The struggle between swamp and petty streams along the northern border was seen in l'Espérance, where, within little more than 600 feet, the great coal mass is broken into thin beds of carbonaceous shale separated by coarse material.

The area in which this accumulation was made embraces not far from 1,000 acres. The abundance of mineral charcoal (fusain) shows that the surface of the swamp had frequently only a thin covering of water and that, at times, parts of it were bare; cannel and cannel shale mark the presence of pools into which fine silt and vegetable mud were carried; while the constant irregularity and impurity of the Banc supérieur make clear that toward the close the bog was exposed to overflows of very muddy water, which at length became so frequent as to destroy the vegetable growth. The Banc des Chavais is an ordinary phenomenon, not unlike the "sandstone faults" of other regions. An outlet of the Colombier had pushed its way across the swamp. Shallow at first, it carried only fine silt; during a flood or during temporary obstruction of the main stream, it deepened its channel and for a time it may have been the chief outlet, carrying down the coarse material to be mingled with portions of the swamp itself. But it aggraded its lower reaches through the bog; becoming shallow, it carried only fine silt and at length was obliterated by the swamp growth. Irregularities in partings indicate lines of petty streamlets following temporary channels.

There is said to be nothing resembling an ancient [1] soil of vegetation and this is taken to be evidence against the hypothesis of origin from plants *in situ*. No information is given as to what are the necessary characteristics of such a soil, but it can be said positively that underclays with *Stigmaria* are wholly wanting. *Stigmaria* occurs only in the roof shales of the Grande Couche on the west side of les Pégauds, where it is associated with *Lepidodendron*; neither genus has been found on the east side. *Sigillaria* is unknown, save by a single cicatrix discovered in the Lower measures.[2] The absence of these forms does not concern the matters at issue; it shows only that the coal was formed from other plants, such as have contributed to coal-making elsewhere as well as here. A bed of impalpable clay is not necessary for the formation of a swamp; the sandy clay underlying the Grande Couche is crowded with vegetable remains and it is clayey enough to prevent downward drainage.

[1] FAYOL: Commentry, p. 239.
[2] FAYOL: Commentry, p. 239, 132.

Renevier recognized that a strong argument in favor of origin from plants *in situ* exists in the conformity of the Grande Couche to its inclosing beds. He insisted that if the coal had been formed of in-brought vegetable matter, that material, being of low specific gravity, should be found only on the rim of the delta cone and in the center of the basin; so that the original declivity of the deposit should be very small; but in this area of the Pégauds the coal bed shares in the general dip, 25 to 50 degrees, according to the locality.[1]

This observation by Renevier appears to have been regarded as unimportant; but it is exceedingly important, for during the Grande Couche time the distance from the edge of the plain to the outlet was nowhere more than two miles and for the most part not more than one mile, so that during flood time the whole surface of the little pond was in rapid movement toward that outlet. It was impossible for the velocity of water flowing in from flooded streams to be checked so rapidly as to permit precipitation of fine materials, the equivalents of impalpable mineral materials, to begin within a few rods. The pond was not a deep body of great size, but it was a small body with an outlet. The fine clays and the vegetable matter, including the trees, would find their way to the outlet; if that were shallow, the velocity would be checked there and the coal deposit should be found along the southern border of the basin, not on the border of the delta plain.

The hypothesis that the Grande Couche was once a *Cordaites* swamp demands shallow water in the Pégauds pond; the other hypothesis requires that the pond be deep.

From 500 to 800 meters of stratified rock, much of it very coarse, intervenes between the Grande Couche and the northern border of the basin; the less coarse materials had been carried farther out. According to Fayol's map, the Colombier had dug for itself a valley comparable to that of the Bourrus, yet its delta had been pushed out only one kilometer, when that of the Bourrus had almost reached the southern border. The explanation is simple. The Bourrus was cutting its way through granites and carrying vast quantities of coarse stuff; the Colombier was cutting its way first through sedimentary rocks of Lower Carboniferous age and afterward through mica schist and gneiss, rocks readily disintegrating and yielding comparatively fine material, most of which was not dropped at once but was spread over the bottom of the pond. If one consider the character of the rocks, he is apt to conclude that the amount of detritus carried out by the Colombier was greater than that transported by the Bourrus — and, if one may judge by the map, Figure 3, this coincides with Fayol's opinion. The northern portion of the Pégauds pond must have been very shallow

[1] Réunion etc., pp. 67, 68.

when the Grande Couche began, and in all probability the bottom fell off very gradually southward.

Any hypothesis to be satisfactory must account for deposits of rock above the Grande Couche. But before this matter can be taken up, some other features of the Pégauds area must be considered.

Many of the observed irregularities in stratification are due to the manner of deposit; but there are others which were brought about after the rocks had been consolidated.

Possible early erosion of the Grande Couche.

The conditions observed in the Grande Couche within l'Espérance and Longeroux are perplexing, and the writer's observations do not suffice for final explanation; no assistance can be obtained from the record as given by Fayol.

In an exposure at the southerly end of l'Espérance the coal and its overlying shale have been planed off and the fine dark shales overlie it unconformably; in the neighboring trench of Longeroux, the same condition is observed, except that the plane of contact rises westwardly. Midway in Longeroux and at a score of feet lower the coal has been cut off in the same way, but the fault features are not so distinct, as the overlying shales rest on the coal instead of meeting it with their edges; but this is evidently the same plane as that at the end of the trench, for that inclines southwardly. This faulting does not affect the Banc des Brouillages, the lowest portion of the Grande Couche, which is continuous from below the plane of faulting all the way up the wall and the fine dark shales rest against it with the same dip.

The Grande Couche in l'Espérance shows two broken folds; in Longeroux, the bed is crushed and folded as shown in Figure 2 and Plate XIX, figure 2, the pressure as in l'Espérance having been in direction of the strike. In this Longeroux fold, a shale is involved of which no traces appear above the coal, and the fine dark shales, not sharing in the disturbance, thin out gradually on the jagged upper surface of the coal bed. The Banc des Brouillages does not seem to have been affected. That the coal had been consolidated before the folding took place appears from the features already described on an earlier page.

These disturbances were not contemporaneous. The folding is along the strike and the faulting along the dip. It is quite possible that the folding was due to a disturbance which brought the Grande Couche again to the surface and exposed it to erosion; in which case it would be the source of the pebbles seen in higher rocks. The top of the fold in Longeroux has

not been eroded. The faulting may be due to the great disturbance which distorted the Glissement beds; the other to an abrupt change in the rate of subsidence of the basin.

The Glissement de L'Espérance.

The so-called Glissement de l'Espérance, of which the features are shown in Plate XVIII, figure 1, and Plate XX, figure 2, is the most notable of the disturbances observed. Fayol thus describes and explains it:

> During and after the formation of the Grande Couche, coarse materials, carried by the Colombier river, were stopped at the border of the lake, forming some beds of pebble rock (poudingue) with steep inclination. At a certain moment, in consequence of the accumulation of plants and mud, the poudingues have slipped, pushing before them the mud, not yet consolidated, corroding and folding the vegetal bed. In this movement they were turned up in some points so as to dip in direction contrary to that of the Grande Couche. After this movement, the sedimentation resumed its ordinary course; the irregularites of deposit were effaced by the new beds, and when the formation of the Grès Noirs took place, all trace of the great Glissement de l'Espérance had disappeared.[1]

It is with no little regret that the writer is compelled to dissent from this ingenious explanation as well as from the description of the conditions.

The statement that after these Glissement rocks were deposited the irregularities were effaced by later sedimentation, may be accurate; but that cannot be determined now, as no newer beds overlie those of the Glissement. The trough now occupied by the light colored sandstones, shales and occasional pebbly layers, was formed long posterior to the deposit of the Grès Noirs. A quarry, recently opened at the southerly end of the Longeroux trench, shows the trough filled with much the same type of rock as at the other end and having as its wall the yellow sandstone which overlies the black shale of the Grès Noirs. The topography beyond this quarry is such as to make probable that in that direction still higher beds occur in the wall. It must not be forgotten that at most there remains only the bottom portion of this trough, as the region has suffered great erosion; even in recent times it has been base-leveled into broad benches. The rock filling the trough is unlike any seen elsewhere in the basin, except at the northwest near Chamblet-Néris station.

The late date at which the deposit was formed makes unacceptable the suggestion that it was caused by a slide on the delta slope, or the other that its formation has something to do with irregularities in the Grande Couche. The natural explanation is that after the lake had been filled, a stream eroded

[1] FAYOL, Réunion etc., pp. 35, 36, 37.

a wide valley perhaps 200 feet deep, in which at a later time were deposited sands and silts; just as has happened within recent time at many places within the basin. One of these later valleys has been exposed in the southerly portion of the Longeroux trench; it is filled with the gravels of the alluvial deposit now covering the basin.

The Glissement sandstone, containing much kaolinized feldspar and for the most part only moderately coarse, was subjected at last to great pressure, by which its beds were folded into a complex syncline, while the fine shales and the Grès Noirs beyond were pushed into recumbent folds.

The cause of dislocation.

This leads to the consideration of another matter. The dip in most of the exposed area within les Pégauds is approximately 30 degrees, the Grande Couche showing the same dip as the other beds; and this has been supposed to be the original slope of the beds. There is no room for doubt that beds can be deposited with that slope, especially if the delta be formed in a deep water-basin; Fayol has proved this by experiment, but the question is not what is possible but what is probable. And there seems to be good reason for hesitation before accepting the propositions that the steep dip is approximately the original and that the basin was deep.

There is abundant evidence in many portions of les Pégauds that after consolidation the beds were exposed to tremendous pressure such as accompanies folding. Even on the westerly side in the trench of Pré-Gigot, the black shales accompanying the Grande Couche are rolled in some places like pastry and show polished surfaces. Occasionally the coal itself is crushed into petty lentils which have been rubbed and polished. It is by no means improbable that the curious flexures seen in several beds of shale crew due to the yielding and slipping of soft between hard beds. Some even of the petty faults with small vertical extent seem referable to disturbance after the rocks had been consolidated. The evidences of dislocation increase eastwardly, reaching the extreme in the southerly portion of l'Espérance and the adjacent portion of Longeroux.

The disturbance took place after sedimentation had ceased in the area examined, and its cause must be sought in the northeast portion of the Pégauds area.

When the basin had been filled, a great outflow of igneous rock occurred on the northeasterly side and its dikes extended even into the Trancehé de Saint-Edmond, midway along the outcrop. This rock did not break through the rocks surrounding the basin, but through the coal measures themselves not far from the edge of the Grande Couche. Some dikes appear even in the

area of les Ferrières,[1] but the great mass came to the surface near the area of extreme disturbance. This outburst coming at the close of Commentry's history made the thrust which doubled up the Glissement beds, pushed the rocks beyond and increased the dip throughout the Pégauds area. Fayol, in his reply to Renevier's objections, grants that this outburst affected the rate of dip, but only to increase it by about 25 degrees; and he maintained that it had nothing to do with causing the prevalent dip of about 30 degrees.[2]

Fayol's position is right to some extent, but one must allot to the dioritine outburst a much greater and wider influence than he admits. The dikes are present even in the area of les Ferrières, so that there is reason to believe that the mass extends under the coal measures of the entire basin, or at least that it extends across the northerly portion, thus causing a serious dislocation in that whole region.

Yet, even with that extension, there remains a serious dip to account for. Renevier's suggestion[3] that the synclinal structure observed in an east and west direction is due to gradual subsidence through carbonization and compression of the soft materials, is in accord with conditions described in Pennsylvania, Iowa and other states. The gradual change in mass certainly accounts for the synclinal structure and for a dip of five degrees; the intrusion of a sheet of dioritine accounts for the crushing and polishing as well as for much of the dip in the western part of the areas; but these do not account for all of the features.

Secular movements in the basin.

This leads to the last matter to be considered in this paper, which already has exceeded the limit intended at the outset.

The form of delta-hypothesis under consideration insists upon great depth of the basin as a pre-requisite. The writer is far from saying that it should be rejected on the ground of inherent improbability, for such a depression in the surface is not in any sense impossible. But if a hypothesis can be presented which is more in accord with what are known to be the normal conditions in nature and which, at the same time, meets equally well the requirements within this area, it is preferable.

The region of which the Commentry basin forms a small part had been undergoing prolonged and serious disturbance. De Launay's admirable synopsis makes this clear. A great fault marks the westerly side of the syncline for much of its length; though that is not recognizable on the west

[1] Fayol: Commentry, pp. 44–47.
[2] Réunion etc., p. 68.
[3] Réunion etc., pp. 67, 68.

side of Commentry, yet there, as well as for some distance eastwardly along the southern border, the coal measures abut against the granite. It would seem wholly in accord with the observed phenomena to suppose that the unstable conditions continued and that there was a differential sinking of the bottom of the basin, increasing toward the southwest and south; not a constant but an intermittent subsidence, as is known to be the condition in faulted regions. During a long period of very gentle subsidence, the Grande Couche and the immediately overlying beds accumulated; an abrupt adjustment after the period of comparative quiet would bring about serious changes in the watercourses of the little area, during which the black shales of the Grès Noirs could be formed by destruction of exposed portions of the Grande Couche. Even the distortion of the Grande Couche in the Longeroux trench might be due to a disturbance of this type.

A differential subsidence combined with the effect of compression and carbonization would account for the high dips which have been regarded as original. The distribution of the coarse materials as well as the absence of horizontal beds alike favor the supposition that the water was shallow and that the great apparent depth is due to subsidence. This hypothesis is merely the outgrowth of de Launay's presentation of the character of movements throughout the region under consideration. He asserts, rightly enough, that there is nothing incompatible with the delta theory in the supposition that movements such as he describes had taken place during the formation of the coal and had given to the lake, step by step, the great depth which is found to-day.[1]

Appendix.

Jukes on formation of coal beds.

One cannot fail to recognize the typical features of delta deposit everywhere in the excavations at Commentry and students should be grateful to the engineer who chose this mode of mining, for there the conditions, which elsewhere have been only surmised, are exposed in full day. Study of these phenomena led Fayol to formulate his doctrine, which, he says, is not absolutely new; it was entertained by the first savants who studied coal, but afterwards hypotheses as improbable as insufficient were presented. He is confident that these will be rejected when men discover that simultaneous transport of vegetable and mineral materials can give distinct beds and when they have seen that the delta theory explains all of the coal measure phenomena.[2]

---

[1] Réunion etc., pp. 101, 102.
[2] Commentry, pp. 19, 20.

Whether or not this delta theory explains all of the coal measure phenomena, even whether or not it explains those of the little basin of Commentry, is not, as the reader must have recognized, an open question in the writer's mind. But be that as it may, Fayol is wholly accurate in stating that the theory, as presented by him, is not absolutely new for it is quite old. One can hardly believe that Jukes's brilliant work, first published prior to 1850 and republished in 1859,[1] had been forgotten in 1889; yet there is no doubt that it was then unknown to many eminent geologists in France and that it is still unknown to some who are engaged in the investigation of coal phenomena.

Unquestionably, as Fayol says, the greater number of geologists who have devoted themselves to the study of coal, have not accepted the doctrine that coal is derived from transported vegetable matter; but there have been very few who did not see in the structural arrangement of materials full evidence of delta deposit; many of the phenomena, described by Fayol in such detail, have been regarded by others as, so to say, elementary facts, deserving mostly of only passing reference. But Jukes in his discussion went farther and applied the laws of delta deposit to transported vegetable matter in order to account for the origin of coal beds themselves — and his arguments are very largely the same as those employed by Fayol, 40 years afterwards.

Certain features in some of the important coal beds led Jukes to say, "they have only confirmed me in my belief in the entirely subaqueous deposition of these coals." He bases his opinion upon

the "rolls," "swells" or "horsebacks" in the coal,
the "rock faults" or great masses of sandstone in the coal,
the branching of coal beds,
the expansion of coal beds toward the direction whence the mineral materials came.

He discusses fully the distribution of mingled materials and asserts, the italics being his own, "It appears to me that the phenomena of lamination and stratification of beds of coal and their interstratification and association with other stratified rocks are explicable *solely by the relation of the specific gravity of their materials to the action of moving water*, and the consequent diffusion of those materials through the mass of that water."

The variation in thickness and other changes in the coal beds "are distinctly referable to the action of water in transporting materials of different kinds which have been committed to it": and further he insists on "the obvious 'delta-like' or 'bank-like' form which the coal measures of South

[1] JUKES, J. BEETE: The South Staffordshire Coal Field. Mem. Geol. Survey of Great Britain, 2d. edition, pp. 202–206. London, 1859.

Staffordshire must have originally possessed and the perfect resemblance they must have had to an undisturbed subaqueous accumulation."

In one important respect Fayol differs from Jukes. The latter evidently recognized that only a small part of the vegetation growing upon a drainage area could ever find its way to deposition in a basin, for he thought that the whole of the coal measures, coal included, was deposited by one connected operation of the same physical forces upon these materials through an indefinite but immensely long period of time. Fayol's calculation based evidently on the conception that the vegetation was dense and continuous over the whole drainage area, while, at the same time, it was in constant transference to the basin, is that 170 centuries sufficed for formation of the whole series at Commentry.

PLATE XV.

FIG. 1. TRANCHÉE DE FORÊT.

Opening in the Grande Couche in foreground. The white material on right side is the sandy underclay.

FIG. 2. GRANDE COUCHE IN L'ESPÉRANCE.

Banc des Roseaux at top on right side; the irregular Banc supérieur rests on the Banc intermediare in the background.

PLATE XVI.

FIG. 1. TRANCHÉE DE L'ESPÉRANCE.

Nonconformity between the Grande Couche and the overlying dark shales.

FIG. 2. TRANCHÉE DE L'ESPÉRANCE.

Westerly wall exhibiting irregularity of deposit of Grès Noirs above and gray shales below.

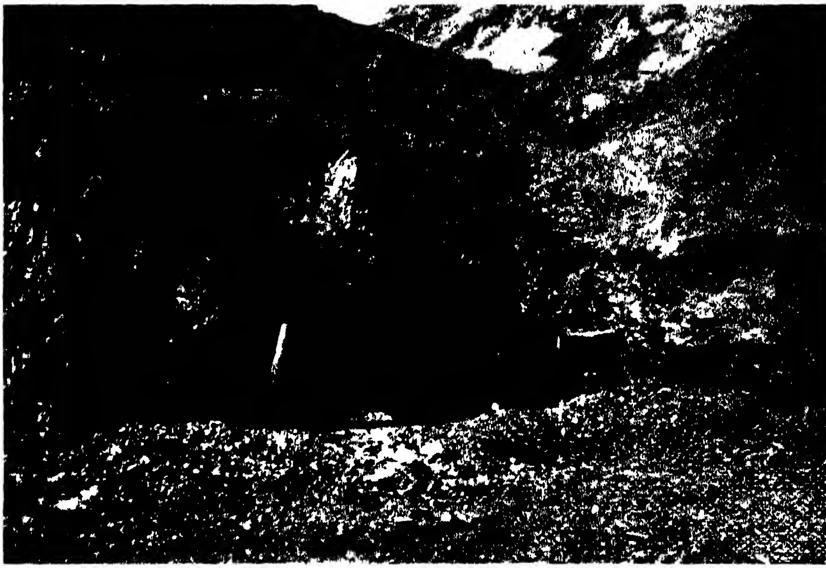


PLATE XVII.

Fig. 1. Tranchée de l'Espérance.

Southwesterly corner showing structure of the Grès Noirs group.

Fig. 2. Tranchée de l'Espérance.

Southerly wall showing faulting in the dark shales.

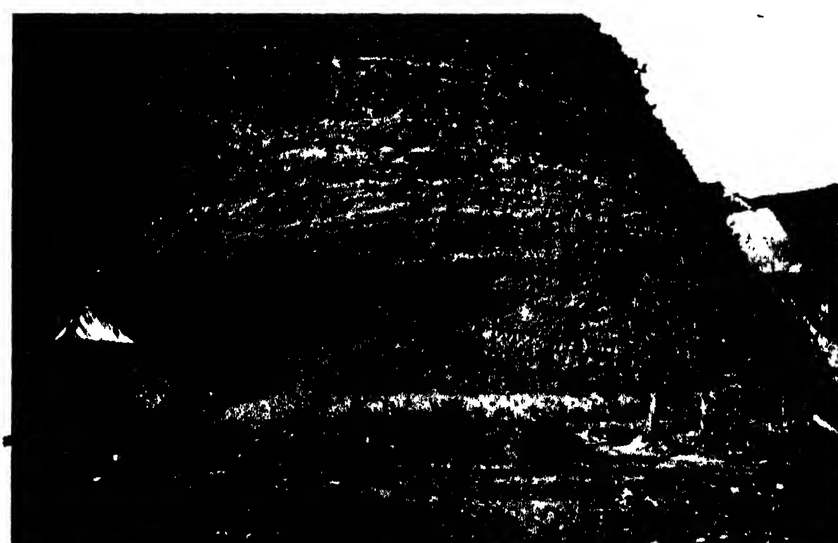


PLATE XVIII.

FIG. 1. GLISSEMENT DE L'ESPÉRANCE.

Southerly wall of l'Espérance.

FIG. 2. TRANCHÉE DE LONGEROUX.

Recumbent fold in black shales of Grès Noirs. There are two photographs on this film. The fold shown at right of stairway belongs in the cliff at left of stairway.

2

PLATE XIX.

FIG. 1. TRANCHÉE DE LONGEROUX.

Upper sandstone and black coaly shales of Grès Noirs.

FIG. 2. TRANCHÉE DE LONGEROUX.

Grande Couche at left; dark shales and folded sandstones of Grès Noirs in background.

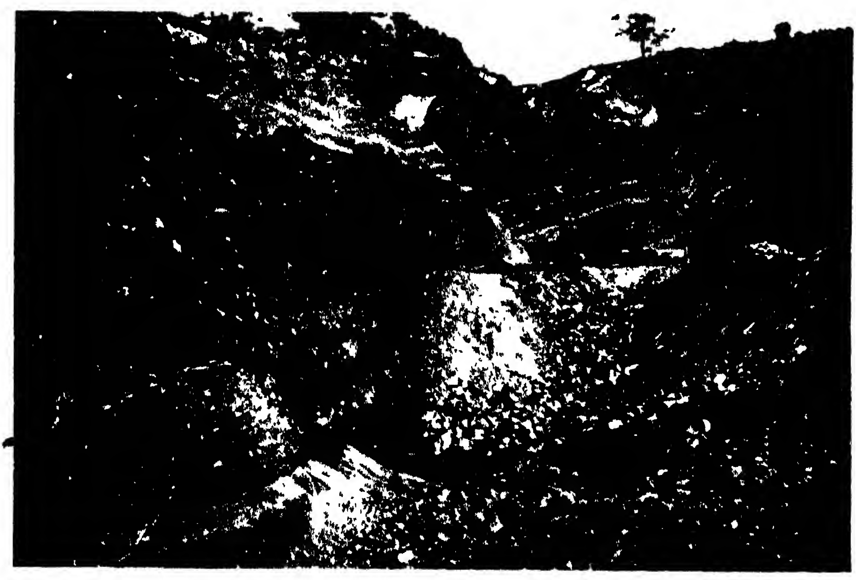


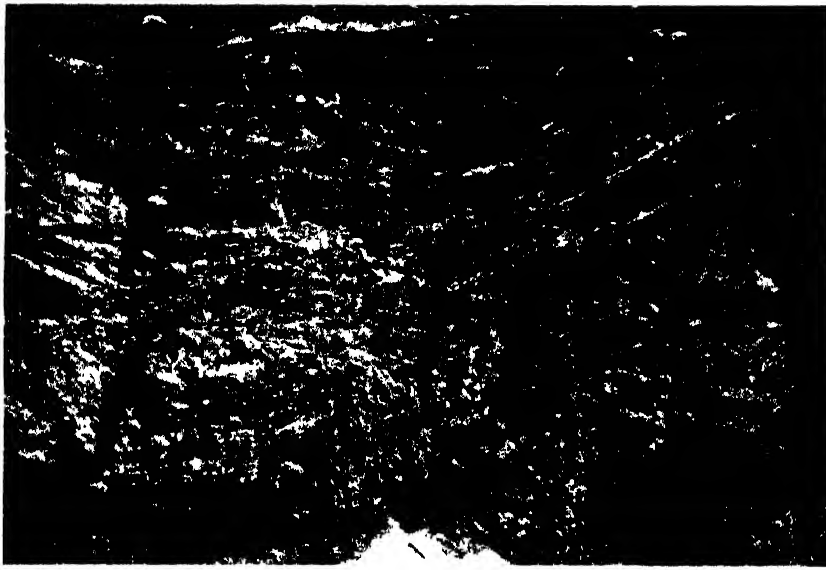
PLATE XX.

FIG. 1. TRANCHÉE DE LONGEROUX.

Fault between Grande Couche below and dark shales above.

FIG. 2. TRANCHÉE DE LONGEROUX.

Glissement de l'Espérance and flexed dark shales.



[ANNALS N. Y. ACAD. SCI., VOL. XIX, No. 9, Part II, pp. 205–224, Plates XXI-XXII, 2 March, 1910.]

SOME NEW OR LITTLE KNOWN AMERICAN SPIDERS.

BY ALEXANDER PETRUNKEVITCH, Ph.D.

The present article contains descriptions of a few American spiders belonging to two separate collections, one of which is in the American Museum of Natural History and the other in my private possession. The genera, unless otherwise stated, conform to the definitions given to them by Eugène Simon in the second edition of his "Histoire Naturelle des Araignées," the only extensive work on the subject. It has been necessary to establish two new genera. One of these, *Moenkhausiana*, belongs to the family Lycosidæ and is characterized by the unusual structure of the spinnerets and the proportion of the legs. The other genus, *Theridionexus*, I place provisionally in the family Theridiidæ, although the spider for which I have established this genus has many structures characteristic of Argiopidæ.

Uniform terminology is essential to a correct description of species. Finding the old one inadequate and confusing, I proposed a new one in an article entitled "Contributions to our Knowledge of the Anatomy and Relationships in Spiders," in the Annals of the Entomological Society of America, Volume II, 1909. For an understanding of the principles underlying this terminology, I refer the reader to this article. The following abbreviations will be used throughout the present article: *Episynaxial surface*, EPS; *Hyposynaxial surface*, HYS; *Prosymmetrical surface*, PRS; *Retrosymmetrical surface*, RES. For the convenience of the reader I may state that the episynaxial surface in spiders is almost synonymic with dorsal; hyposynaxial with ventral. In the old terminology, however, the words anterior and front were often used to designate the hyposynaxial surface of the first femora. The prosymmetrical surface corresponds to the inner surface of the front legs and the outer surface of the hind legs, while the retrosymmetrical surface corresponds to the outer surface of the front legs and the inner surface of the hind legs. In the chelæ, *promargin* stands for superior or anterior and *retromargin* for inferior or posterior.

All measurements are given in millimeters.

ZOROPSIDÆ.

1. **Acanthoctenus Marshii** F. Cambridge, Ann. Mag. Nat. Hist., 6th ser., vol. xix, p. 103. 1897.

Plate XXI, Fig. 1.

One specimen of this large spider was caught by Prof. W. J. Moenkhaus at Poço Grande, Brazil, in 1897. It is a mature female, and the measurements show that there can be no doubt as to its identity. There are, however, two points in which this specimen differs from the type, both margins of the chelæ are armed with three teeth and the epigynum although similar to that figured by F. Cambridge shows difference in structure, as may be seen by comparing the type with Plate XXI, fig. 1. I do not, however, consider these differences sufficient to constitute a new species. It is true that the number of teeth on the margins of the chelæ is a remarkably constant character and has been used by Cambridge and Dahl for the separation of species, but I have seen exceptions to it in other families of spiders. On the other hand, the shape of the epigynum changes after copulation and still more after the eggs are laid.

Total length, 16.5; cephalothorax, 7.5 long, 6 broad between second and third legs; legs in order 4123; first coxa the longest.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	8.5	13 0	8.0	2.5	32.0
II	7.5	11.0	7.0	2 0	27.5
III	6.5	8.5	6.5	2 0	23.5
IV	8 5	11.0	10.3	3.0	32.5

Spines on legs: *First leg.*— Femur, EPS, 12 spines in 3 rows as follows: 4 in the pro, 3 in the meso and 5 in the retro row; tibia, HYS, 8 pairs of long spines, PRS and RES, with an apparently variable number of small spines; metatarsus, HYS, 4 pairs of long spines, PRS, 1 proximal spine, RES, 1 proximal spine. *Second leg.*— Same as first. *Third leg.*— Femur same as first; tibia, HYS, 3 pairs, PRS, 2 spines, RES, 2 spines, EPS, 1 row of 3 spines; metatarsus, EPS, 1 spine, HYS, 5 pairs, PRS, 4 spines, RES, 4 spines. *Fourth leg.*— Same as third; the only difference is in the number of spines in HYS of the metatarsus, there being four pairs instead of five. Patellæ of all four pairs of legs have one PRS and one RES spine.

Color in Alcohol: Mostly light brown with dark brown mandibles; on each side of cephalothorax and covering about one fifth of its entire width, a darker submarginal band; abdomen somewhat grayer, with three pairs of indistinct crosslines on back; lip considerably darker than sternum, nearly as dark as mandibles, but its tip yellow; along front edge of lip a row of dark bristles each sitting in a nearly black cupula; cephalothorax covered with short black and white hair; face with long black bristles and short white hair; sternum longer than broad, sparsely cov-

ered with short hair; abdomen covered with short yellowish hair with few dark hairs scattered irregularly and with four rows of long tufts; the two middle rows of six tufts each, the side rows probably of four tufts each, this number being uncertain, however, owing to the poor preservation of the tufts; scopulæ yellow; calamistrum small, occupying scarcely more than one tenth of the metatarsus (the second proximal tenth) and consisting of irregularly distributed hair; spinnerets yellowish brown; upper pair a little thinner and longer than the lower; cribellum divided in two.

PATRIA: Brazil (Poco Grande, Province Sao Paulo).
COLLECTION: A. Petrunkevitch. One mature female.

OONOPIDÆ.

2. **Orchestina saltabunda** Simon, Ann. Soc. Entom. France, vol. lxi, p. 447, pl. ix, fig. 12. 1892.

Plate XXI, Figs. 2, 3.

This little spider was described by Simon from Venezuela. On June 26, 1907, a mature male was caught by Mrs. Petrunkevitch in our home at Short Hills, New Jersey. The specimen accords well with the description of Simon. The embolus of the palpus is, however, longer than that figured by Simon. Since this species has not been recorded from the United States, I give a figure of the palpus (Plate XXI, fig. 2) and of the spider as viewed from the side (Plate XXI, fig. 3). Total length of spider, 1.05; cephalothorax, 0.53 long, 0.44 broad between second and third pair of legs.
COLLECTION: A. Petrunkevitch.

DRASSIDÆ.

3. **Melanophora rufula** Banks (sub Prosthesima), Proc. Acad. Phila. for 1892, p. 17, pl. 1, fig. 55; Emerton, Trans. Conn. Acad., vol. xiv, p. 217, pl. ix, fig. 6. 1909.

Plate XXI, Fig. 4.

Banks has described only the female of this spider. Emerton described the male and gave good figures of the palpus in his recent paper which was printed at the time when my plates were already finished. Several mature specimens of both sexes were collected in Onondaga County, New York, by the late H. W. Britcher.
COLLECTION: American Museum.

PHOLCIDÆ.

4. **Spermophora meridionalis** Hentz, Am. Jour. Sci., vol. xli, p. 116. 1841.

Plate XXI, Fig. 5.

During the summer of 1908 a number of males and females were collected in our home at Short Hills, N. J. For a figure of the comb-hair of the fourth tarsus in this species see Petrunkevitch, Ann. Entom. Soc. Amer., vol. ii. plate iv, fig. 12. This comb is homologous with the comb of the Theridiidæ. Its presence on the fourth tarsus is a character common to both families. It always occupies the middle line on the hyposynaxial surface, but in the Theridiidæ the combhair is long, heavy, almost bristle-like, while in the Pholcidæ it may be recognized only under high magnifying power.

The male palpus of *Spermophora meridionalis* has never been figured, hence I give a figure of it here.

THERIDIIDÆ.

5. **Latrodectus mactans** Fabricius (sub Aranea), Entom. Syst., vol. ii, p. 410. 1775.

Dahl has made the attempt to divide this species into two species, the one of which he calls *mactans* Fabricius and the other *insularis* Dahl with two subspecies, *insularis insularis* from St. Thomas and *insularis lunulifer* from Hayti. Such division is entirely unwarranted. I have specimens in my collection from the United States, Jamaica, Brazil and Patagonia, and I do not find any characters sufficient for the separation of this well known species into either more species or subspecies. The differences are of minor value, not more than may be attributed to the influence of local conditions. The specimens from Jamaica and from many localities of Mexico are in no way different from those found in the United States. The specimens from Patagonia have a very marked red band in the posterior third of the abdomen; but the palpus and the epigynum are in every detail the same as in the other specimens. On my recent trip through southern Mexico I was very much surprised to find that in the plains around San Geronimo, on the Isthmus of Tehuantepec, *Latrodectus mactans* is much more brilliantly colored than the specimens which I collected in the tropical forests of the same Isthmus. The markings on the abdomen of the mature female are the same as in young spiders of other localities, but the red stripes are so heavy

and so brilliant that the first impression is that of a coral red spider. Its local name is "*aragna colorada.*" Instead of living under rocks as in Jamaica, it makes its webs some six feet above the ground among the branches of the cactus, where it often hangs with several males. As many as eight males, indeed, were found in one web. And yet no structural difference can be found between this "red spider" and the "black widow" of the southern United States. The *L. insularis* Dahl with its two varieties becomes therefore a synonym of *mactans*.

Theridionexus gen. nov.

Cephalothorax humilis, impressione transversa recta notata; oculorum linea antica recurva, postica levissime procurva; oculi inter se fere æquidistantes, medii antici reliquis minores, nigri; laterales contigui; quadrangulus antice quam postice angustior, postice latior quam longior; clypeus quadrangulo multo latior; chelæ sat longæ, pro margine (superiore) obliquo tridentato, retroma·gine (inferiore) mutico; pars labialis latior quam longior, dimidium laminarum non attingens; laminæ subrectæ; sternum triquetrum, antice truncatum, postice acuminatum; pedes longi, mutici; tarsi unguibus spuriis 2-2 muniti, ungues superiores geniculati, pectinati; unguis inferior muticus; tarsi postici pectine muniti; abdomen globosum, organo stridulante carens.

Typus: *T. cavernicolus.*

6. **Theridionexus cavernicolus** sp. nov.

Plate XXI, Figs. 6, 7. Plate XXII, Figs. 30, 31, 32, 33, 34, 37.

The spider for which I propose the new genus combines the characters of two families. Its general appearance, the long front legs and the globose abdomen and most of all the presence of a well developed tarsal comb speak for its close relation to the family Theridiidæ. On the other hand, the structure of the mandibles, the shape of the cephalothorax and especially the presence of a tibial apophysis in the male palpus are characters which are found only in Argiopidæ. It is, therefore, impossible to place the genus *Theridionexus* with sufficient reason in either of these families; it forms a new, intermediate group. The proposed name expresses to a certain degree the affinities of the genus.

Female.— Cephalothorax, 2.7 long, 2.1 broad between second and third pair of legs; abdomen, 4.0 long; legs in order 1243.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	7.1	7.9	6.8	2 6	24.4
II	5.3	5 7	4 7	2.0	17.7
III	3.2	3.1	2 8	1.3	10.4
IV	5.0	4.6	4.0	1.6	15.2

Male.— Cephalothorax, 2.3 long, 1.9 broad between second and third pair of legs; abdomen, 2.5 long.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	8.6	9.3	8.1	2.9	28.9
II	6.7	7.2	6.2	2.4	22.5
III	3.9	3.8	3.4	1.1	12.2
IV	5.5	5.1	4.4	1.9	16.9

Legs in both sexes with long black hair, arranged in regular rows; same kind of hair on sternum; cephalothorax nearly glabrous, with a very few black hairs in cephalic region; abdomen covered with short brown hair; spinnerets small; colulus absent. Cephalothorax shape apparent from Plate XXII, fig. 31; head separated from thorax by deep sulci uniting in the transverse groove; face and mandibles represented in Plate XXII, fig. 32; promargin of chelæ with three teeth of which the distal is longest and strongest; lip considerably broader than long, not reaching the middle of the laminæ; sternum triangular, broadest between first and second pair of coxæ, in front a little narrower, but first coxæ are still widely separated from each other; palpal claw in female with a series of eight teeth, growing gradually longer towards the distal end; superior tarsal claws distinctly geniculate, with five or six teeth of which the distal is longest; inferior tarsal claw smooth; each tarsus has, besides, two pairs of serrated bristles (Plate XXII, fig. 34); fourth tarsus with a well developed comb; male palpus with a tibial apophysis (Plate XXI, fig. 6); epigynum as figured (Plate XXI, fig. 7).

Color: Body and legs in both sexes light brown; abdomen more or less uniformly grayish.

Patria: Jamaica, W. I. In the Peru Cave near Malvern, Santa Cruz Mountains. Collected May 12, 1905. I found the spiders at a considerable distance from the entrance to the cave, which is supposed to extend over six miles. They were hanging in loose webs on the wall of the cave. These webs consisted of a few irregular threads. The spiders seem to feed on little flies which abound there.

Collection: A. Petrunkevitch. Five mature females and one male.

ARGIOPIDÆ.

7. **Alcimosphenus licinus** Simon, Hist. Nat. Araign., vol. i, p. 935. 1895.

I collected two mature females of this beautiful spider in the environments of Port Antonio, Jamaica, W. I., in February, 1905. They were hanging in their webs in low grass on the edge of the road. The red velvety color of the body is very beautiful, but it becomes much duller in alcohol. Both specimens agree perfectly with the description of Simon and the figure given by F. Cambridge of a specimen from the Bahamas.

8. **Alcimosphenus bifurcatus** sp. nov.

Plate XXI, Fig. 8.

This species is considerably smaller than the preceding, if one may judge by the two immature females which I collected in Jamaica.

Total length, 6.2; cephalothorax, 1.9 long, 1.7 broad between second and third pairs of legs; legs in order, 1423.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	2 3	2.9	2.2	0.9	8.3
II	1.6	2.5	1.9	0.9	6 9
III	1.3	1.2	1.0	0.6	4 1
IV	2.4	2.1	1.8	0.8	7.1

All eyes subequal in size; side eyes contiguous; front row of eyes recurved, second row nearly straight; quadrangulus longer than broad; clypeus as high as quadrangulus is long; promargin of chelæ with two, retromargin with four teeth; body smooth; legs without spines; at distal end of each patella a bristle on the EPS.; fourth femora with the two characteristic rows of long curved hair.

Color in Life: Cephalothorax and abdomen bright red, the latter extending considerably beyond spinnerets, bifurcated at extreme end, the two lobes entirely black; mandibles, palpi, laminæ, lip, sternum, venter and all coxæ and trochanters red; spinnerets red with black ends; femora and patellæ greenish black; tibiæ, metatarsi and tarsi of first pair, metatarsi and tarsi of second pair yellow; proximal end of fourth femur red, proximal ends of fourth tibia, metatarsus and tarsus yellow, rest of these segments black; two little round white spots on venter halfway between genital groove and spinnere s.

Patria: Jamaica, W. I. (Port Antonio and Castleton). Collected in February, 1905, in low grass along the road.

Collection: A. Petrunkevitch.

9. **Epeira solitaria** Emerton, Trans. Conn. Acad., vol. vi, p. 299, plate xxxv, fig. 3. 1885.

Epeira nigra id. ibid. vol. ix, p. 402, Plate i, fig. 1. 1894.
Epeira angulata Emerton (nec Clerck) ibid. vol. xiv, p. 198. 1909.

In his "Supplement to New England Spiders," Emerton considers his *silvatica*, *nigra* and *solitaria* all to be varieties of *angulata* Clerck. From examination of European specimens of *angulata*, I conclude, however, that the latter is distinct from the American species. It seems to me doubtful whether typical *angulata* has ever been recorded from the new continent. It is not impossible that *solitaria* and *nigra* will prove to be local varieties of *sylvatica*. Before sufficient material can be examined, however, I prefer to consider *solitaria* a separate species and *nigra* a smaller, dark variety of the same. I have carefully examined Emerton's types at the Harvard Mu-

seum and compared them with the specimen now before me. The description of Emerton is so brief that I think it wise to describe in detail the structure of the specimen from Onondaga.

Total length, 12.0; cephalothorax, 6.7 long, 5.4 broad between second and third pairs of legs; legs in order 1243.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	7.0	9.3	5.1	2.0	23.4
II	6.5	8.5	4.5	1.9	21.4
III	4.8	5.0	2.7	1.3	13.8
IV	6.5	7.1	4.7	1.7	20.0

Thoracic part of cephalothorax nearly circular with deep depression a little behind its center and a narrow longitudinal sulcus running from the depression forwards a little beyond the meeting point of the cephalic sulci; sides of cephalic part parallel, distance between edges, 2.5; clypeus narrow, 0.350; all eyes on prominent tubercles; diameter of AM, 0.294, AL, 0.168, PM, 0.210, PL, 0.168; distance between inside edges of AM, 0.210, of PM, 0.168; distance between side eyes and middle eyes equal to one millimeter; quadrangulus broader in front than behind, nearly as long as broad in front (0.700 long and 0.742 broad); side eyes contiguous; in middle of quadrangulus two small hairs; a strong bristle between middle and side eyes; sternum longer than broad (3.3 by 2.0) truncated in front, produced into a sharp point behind; coxæ of first pair with dark hump at distal end; coxæ of second pair with stout conical spur at base; coxæ of fourth pair contiguous; femora of first and second pair and tibiæ of second pair distinctly thickened; legs covered with numerous spines on all members; especially heavy spines on second tibiæ; a row of modified spines on HYS of first, second and third femora; in first and second femora the row is formed by five very short proximal and three long distal spines, abdomen with two strong humps in front; palpus as figured by Emerton; whole cephalothorax covered with white hair, becoming long towards eyes; hair on abdomen of three kinds: very short white, long white with dark base and nearly black hair on the humps and spinnerets.

Color in alcohol: Cephalothorax brown, rather reddish; sternum lighter brown with more yellowish tint; back of abdomen with white spot in front, with indistinct folium, otherwise grayish brown; legs brown, tibiæ lighter in middle third; metatarsi and tarsi darker towards end, ventral side uniformly light brown; spinnerets somewhat darker; tips of maxillæ and of lip light yellow.

Patria: Onondaga County, N. Y.

Collection: American Museum. One mature male collected by the late H. W. Britcher.

10. **Micrathena horrida** Taczanovsky (sub Acrosoma) Hor. Soc. Ent. Ross., vol. ix, p. 21, fig. 31. 1872.

nec *M. horrida* Simon, Hist. Nat. Araign, vol. i. 1895

Plate XXI, Figs. 9, 10, 11.

The description given by Taczanovsky is exact and his figure excellent. If I give here some measurements and the figures of the epigynum and of

the abdomen, it is only because Eugène Simon has incorrectly described, under the name *M. horrida* Tacz., a spider which belongs in all probability to a new species. I have three specimens of *Micrathena horrida* in my collection. One is a mature female from São Paulo, Brazil, collected by Prof. W. J. Moenkhaus; the two others are immature females which I collected in the Castleton Botanical Gardens, Jamaica, W. I. All three specimens agree in every detail with the description of Taczanovsky. The following measurements are from the Brazilian female.

Cephalothorax, 2.5 long, 1.7 broad; abdomen from petiolus to anus, 3.0; sternum, 1.2 long, 0.7 broad; clypeus, 0.172; diameter of eyes: AM, 0.105, AL, 0.083, PM, 0.123, PL, 0.083; distance between inside edges of AM, 0.090, of PM, 0.120 of AL and PL, 0.030; distance between outside edge of PM and apex of angle formed by side eyes on each side of head, 0.435; quadrangulus as long as broad, each side measuring 0.345; legs in order 4123.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	1.4	1.6	0.8	0.6	4.4
II	1.2	1.4	0 7	0 55	3 85
III	1 05	0 95	0.45	0 45	2 90
IV	1.7	1.6	0.9	0.6	4.8

All femora with a row of tactile organs on HYS; femora of first pair thickened; no spines on legs.

11. **Micrathena Simoni** (*nomen novum*).

= *M. horrida* Simon, Hist. Nat. Araign, vol. i, p. 850, fig. 898. 1895.
= nec *Micrathena horrida* Taczanovsky.

The number of tubercles or spines on abdomen in *horrida* is 16, as correctly described by Taczanovsky. In *Micrathena Simoni* the number is considerably greater, and the abdomen forms posteriorly a tail which is lacking in *horrida*.

12. **Micrathena oblonga** Taczanovsky (sub Acrosoma), Hor. Soc. Ent. Ross., vol. ix, p. 15, plate vi, fig. 26. 1872.

Plate XXI, Figs. 12, 13.

Cephalothorax, 4.2 long, 3.6 broad; sternum longer than broad (1.6 by 1.4); abdomen (measured on back from anterior edge to base of spines), 9.0 long; venter from petiolus to anus, 4.0; abdomen broad in middle, 5.0; clypeus, 0.24; diameter of eyes: AM, 0.210, AL, 0.150, PM, 0.195, PM, 0.135; distance between inside edges of AM, 0.135, of PM, 0.225, of AL and PL, 0.060; quadrangulus a little broader than long (0.555 broad, 0.525 long); distance between outside edge of PM and apex of angle formed by side eyes on each side of head, 0.825; legs in order 4123.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	5.0	5.2	3.7	1.3	15.2
II	4.5	4.5	3.3	1.2	13.5
III	2.8	2.4	1.5	0.8	7.5
IV	6.6	5.8	4.2	3.8	17.9

None of femora thickened; no tactile organs, only protuberances with hard bristles directed forward and a few irregular spines; similar spines found also on tibiæ; side view of abdomen, Plate XXI, fig. 13; epigynum as in Plate XXI, fig. 12.

PATRIA: Rio Uaupes, border between Colombia and Brazil.
COLLECTION: American Museum. Two mature females.

13. **Micrathena Vigorsi** Perty (sub Acrosoma), Delectus Animalium quas in itinere etc , p. 194, pl. 38, fig. 8. 1833.

Plate XXI, Figs. 16, 17, 18, 19.

Cephalothorax, 5.0 long, 4.0 broad; abdomen (measured on back), 9.3 long, 6.2 broad between second dorsal spines; clypeus, 0.30; diameter of eyes: AM, 0.160, AL, 0.140, PM, 0.182, PL, 0.140; distance between inside edges of AM, 0.168, of PM, 0.280, of AL and PL, 0.070; distance between outside edge of PM and apex of angle formed by side eyes on each side of head, 0.77; quadrangulus a little broader than long, (0.644 broad, 0.602 long); legs in order 4123.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	5.76	5.76	3.44	1 36	16.32
II	5.20	4.96	3.20	1.28	14.64
III	3.76	3.20	1.84	1.12	9.92
IV	6.96	6.08	4.00	1.36	18.32

Tibiæ and metatarsi with very few, weak spines. For figures of abdomen, sternum and epigynum, see Plate XXI, figs. 16, 17, 18, 19.

PATRIA: Rio Uaupes, border between Colombia and Brazil.
COLLECTION: American Museum. Two mature females.

14. **Micrathena sordida** Taczanovsky (sub Acrosoma), Hor. Soc. Ent. Ross., vol. ix, p. 13, pl. vi, figure 25. 1872.

Plate XXI, Figs. 14, 15.

Cephalothorax, 2.40 long, 2.24 broad; abdomen (measured on back), 5.20 long, 6.96 broad between last spines; sternum, longer than broad (1.04 long, 0.72 broad); clypeus, 0.07; diameter of eyes: AM, 0.112, AL, 0.092, PM, 0.126, PL, 0.090; distance between inside edges of AM, 0.098, of PM, 0.140; side eyes contiguous; distance between outside edge of PM and apex of angle formed by side eyes on each side of head, 0.490; quadrangulus almost square (0.364 long, 0.350 broad); legs in order 4123.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	2.80	2.80	1.28	0.56	7.44
II	2.40	2.40	1.20	0.56	6.56
III	1.60	1.20	0.96	0.56	4.32
IV	3.12	2.40	1.76	0.64	7.92

Side view of abdomen, Plate XXI, fig. 15; epigynum, Plate XXI, fig. 14.

PATRIA: Poco Grande, Brazil.

COLLECTION: A. Petrunkevitch. Four mature females collected by Prof. W. J. Moenkhaus.

15. **Micrathena clypeata** Walckenaer, Tabl. Aran., p. 67. 1805.

One mature female from Rio Uaupes on the boundary between Colombia and Brazil. This species was first described by Walckenaer and not by C. Koch, as supposed by Simon.

COLLECTION: American Museum.

16. **Micrathena spatulifera** Simon, Hist. Nat. Araign., vol. i, p. 852, fig. 912, 1895.

Two mature females from Ecuador.

COLLECTION: American Museum.

17. **Micrathena patruelis** C. Koch (sub Acrosoma), Die Arachniden, vol. vi, p. 130, pl. 210, fig. 524, 1839.

Two mature females of this species were collected in 1897 by Prof. W. J. Moenkhaus at Poco Grande, Brazil, in the Province of São Paulo.

COLLECTION: A. Petrunkevitch.

18. **Micrathena bifurcata** Hahn (sub Acrosoma), Die Arachniden, vol. ii, p. 65, pl. 68, fig. 158, 1834.

Two mature females from Poco Grande.

COLLECTION: A. Petrunkevitch.

19. **Micrathena crassispina** C. Koch (sub. Acrosoma) Die Arachniden, vol. iii, pl. 92, fig. 209, 1836.

One mature female from Poco Grande.

COLLECTION: A. Petrunkevitch.

20. **Micrathena gladiola** Walckenaer, Ins. Apt., vol. ii, p. 182, 1842.

Many mature females from nests of mud-dauber wasps, from Poco Grande.

COLLECTION: A. Petrunkevitch.

21. **Micrathena bifissa** Keys (sub Acrosoma), Spirmen Amerikas, Epeiridæ, p. 30, pl. 1, fig. 27, 1892.

Five mature females from Poco Grande.
COLLECTION: A. Petrunkevitch.

22. **Micrathena acuta** Walckenaer (sub Plectana), Ins. Apt., vol. ii, p. 172, 1842.

Four mature females from Poco Grande.
COLLECTION: A. Petrunkevitch.

23. **Micrathena armata** Olivier (sub Aranea), Encycl. Méthod, vol. iv, p. 205, 1791.

Two immature females from the virgin forest in the Cockpit of Jamaica, W. I. I found them hanging in the center of their webs some 10 feet above ground. Collected in May, 1905.
COLLECTION: A. Petrunkevitch.

THOMISIDÆ.

24. **Epicadinus tuberculatus** sp. nov.

Plate XXII, Figs. 20, 21, 22.

Total length, 10.5; cephalothorax, 4.4 long, 4.6 broad at its broadest place, only 1.8 broad in front; abdomen, 6.1 long, trifid; sternum longer than broad, its anterior end with a semicircular notch; both margins of chelæ with two teeth; lip a little longer than broad, scarcely reaching middle of laminæ; clypeus very high, AM sitting a little over middle of forehead; anterior eye row strongly recurved, posterior procurved, broader than anterior; quadrangulus, longer than broad, narrower in front; eyes of first row nearly æquidistant, AM smaller than AL; posterior middle eyes farther apart from each other than from posterior side eyes; legs in order 1243.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	4.3	5 2	2 1	1.4	13.0
II	3.8	4.8	1.9	1.2	11.7
III	1.9	2 9	1.1	0.9	6.8
IV	2.3	2.9	1.1	1.0	7.3

Legs of two front pairs considerably heavier than the four hind legs; spines only on HYS of tibiæ and metatarsi of two front pairs, as follows: in tibiæ of both pairs a row of 3 pro- and 3 retro-spines, on first metatarsi a row of 3 pro- and 4 retro-spines, on second metatarsi a row of 4 pro- and 3 retro-spines; arrangement of trichobothria as follows: first and second legs have 2 trichobothria surrounded by black scales at end of tarsus and 4 at end of metatarsus, also 3 at base of tibia, third leg has 4 tri-

chobothria at end of tarsus, 6 at end of metatarsus and 6 at base of tibia, fourth leg has 4 trichobothria at end of tarsus, 4 at end of metatarsus and 4 at base of tibia; palpus has a group of 7 trichobothria at base of tibia; claws of legs as figured in Plate XXII, fig. 22.

Color in alcohol: Laminæ maxillaries and posterior declivity of cephalothorax uniformly yellow; rest of body and legs covered with numerous tubercles looking like warts; whole body above and underneath mottled with yellow and brown, but colors lighter beneath than above; abdomen extending far behind spinnerets; epigynum as figured (Plate XXII, fig. 21).

Patria: Brazil.

Collection: A. Petrunkevitch. One mature female found by Prof. Moenkhaus at Poco Grande, Prov. São Paulo, Brazil.

CLUBIONIDÆ.

25. **Phrurolithus Britcheri** sp. nov.

Plate XXII, Fig. 23.

Total length, 2.20 mm.; cephalothorax 0.90 long, 0.80 wide; sternum as broad as long (0.60 mm.); legs in order 4123.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	0.90	1.25	0 75	0 50	3.40
II	0.85	1.00	0 65	0 50	3 00
III	0.75	0 85	0 60	0.50	2.70
IV	0 95	1.15	0.85	0 60	3 55

Integuments clothed with thin hair; on epi-medial line of each mandible, about one third its length from base, a stiff bristle; hair on legs, especially on tibiæ considerably heavier than on body; epigynum consists of two separate openings, one above the other, situated in the plane of symmetry; each opening leads into a separate round receptacle by means of a short, curved tube.

Patria: Onondaga County, New York.

Collection: American Museum. One mature female from the vicinity of Cayuga Lake, N. Y., collected by the late H. W. Britcher.

CTENIDÆ.

26. **Ctenus malvernensis** sp. nov.

Plate XXII, Figs. 24, 25.

The size of the specimens in my possession varies considerably. The largest female measures 28 mm. The following measurements were taken from a medium sized female.

Total length, 23.0; cephalothorax, 11.5 long, 8.5 broad in the widest place, and 5.5 broad in front; abdomen, 11.5 long; sternum as broad as long; lip slightly longer than broad; pro-margin of chelæ with 3 teeth of which middle is largest; retromargin with 4 teeth; clypeus equal to 2 diameters of front eyes; quadrangulus broader than long, narrower in front; anterior eyes of quadrangle distinctly smaller; patella and tibia of first pair only slightly longer than patella and tibia of fourth pair (12.9 and 12.4); second row of eyes straight by anterior margin; tibia and tarso-metatarsus of palpus has no pad of short hair; diameter of eyes: AM, 0.40, AL, 0.30, PM, 0.45, PL, 0.45; quadrangulus, 1.20 long, 1.25 broad; distance between outside edges of the front eyes is only 1.15; legs in order 4123.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	9.0	12.9	7.5	3.0	32.4
II	9 0	12.3	7 0	3.0	31.3
III	7.3	9.9	6 5	3 0	26.7
IV	9.4	12.4	10.5	3 5	35.8

Spines on legs: *First leg.*— Femur, EPS, 3 rows of spines, 3 spines in each row, PRS, 1 distal spine; tibia, HYS, 2 rows of spines, 5 spines in each row, PRS, 1 proximal spine; metatarsus, HYS, 2 rows of spi nes,3 spines in each row. *Second leg.*— Femur, EPS, 3 rows of 3 spines each, PRS, 1 distal spine, RES, 1 proximal spine; tibia, HYS, 2 rows of 5 spines each, RES, one proximal spine; metatarsus, HYS, 2 rows of 3 spines each. *Third leg* — Femur, EPS, 3 rows of 3 spines each and 1 additional distal spine, PRS, 1 distal spine, patella, PRS, 1 spine, RES, 1 spine; tibia, EPS, 1 median row of 3 spines, HYS, 2 rows of 3 spines each, PRS, 2 spines, RES, 2 spines; metatarsus, EPS, one spine, HYS, 2 rows of 2 spines each; PRS, 2 spines, RES, 2 spines; tarsus distal verticel of 6 spines. *Fourth leg.* — Femur, EPS, 2 rows of 3 spines each and 1 additional distal spine; patella, PRS, 1 spine; RES, one spine; tibia, EPS, 1 medial row of 3 spines, HYS, 2 rows of 3 spines each, PRS, 2 spines, RES, 2 spines; metatarsus, EPS, 2 spines in middle line, HYS, 2 rows of which one consists of 3 and the other of 2 spines, PRS, 1 row of 3 spines, RES, 2 spines; tarsus, distal verticellum of 6 spines. *Palpus.* Femur, PES, 1 spine at base, 1 in middle and 4 at distal end; patella, RES, 1 spine; tibia, RES, 1 spine, PRS, 1 spine; tarso-metatarsus, PRS, 2 spines, RES, 2 spines.

The following measurements were taken from a medium sized mature male.

Total length, 16.5; cephalothorax gibbous, 9.0 long, 7.5 broad (only 3.5 in front); abdomen, 7.5 long; quadrangulus, 1.20 long, 1.25 broad; distance between outside edges of anterior eyes of quadrangle, 1.15; eyes of second row straight by anterior margins; diameter of eyes: AM, 0.36, AL, 0.24, PM, 0.39, PL, 0.39; legs in order 4123.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	10.0	14.5	10 4	4 3	39 2
II	9 6	13.3	9.6	4.0	36 5
III	8.5	11.0	8.4	3.4	31.3
IV	10.2	13 2	13 0	4.0	40.4

Fourth metatarsus quite straight; tibial spur of palpus as figured (Plate XXII, fig. 25); tibia and tarso-metatarsus of palpus without pad of hair on prosymmetrical surface (inner side of F. Cambridge).

Spines on legs: *First leg.*— Femur, EPS, 3 rows of 3 spines each and 1 additional distal spine, PRS, 1 distal spine; patella, PRS, 1 spine, RES, 1 spine; tibia, EPS, 1 row of 3 spines, HYS, 2 rows of 5 spines each, PRS, 2 spines, RES, 2 spines; metatarsus, EPS, 1 row of 3 spines, HYS, 2 rows of 2 spines each, PRS, 1 row of 3 spines, RES, 1 row of 3 spines. *Second leg.*— Femur, EPS, 3 rows of 3 spines each and 1 additional distal spine, PRS, 1 distal spine; patella, PRS, 1 spine, RES, 1 spine; tibia, EPS, 1 row of 3 spines, HYS, 2 rows of 5 spines each, RES, 2 spines; metatarsus, HYS, 2 rows of 2 spines each, PRS, 2 spines, RES, 2 spines. *Third leg.*— Femur, EPS, 3 rows of 3 spines each and 2 additional spines, one of these is proximal, the other distal; patella, PRS, 1 spine, RES, 1 spine; tibia, EPS, 1 row of 3 spines, HYS, 2 rows of 2 spines each, PRS, 2 spines, RES, 2 spines; metatarsus, EPS, 2 spines, PRS, 2 spines, RES, 2 spines; tarsus; verticel of 6 spines. *Fourth leg.*— Femur, EPS, 3 rows of 3 spines each and 2 additional spines, one of these distal, the other proximal; patella, PRS, 1 spine, RES, 1 spine; tibia, EPS, 1 row of 3 spines, HYS, 2 rows of 3 spines each, PRS, 2 spines, RES, 2 spines; metatarsus, HYS, 2 rows of 3 spines each, PRS, 1 row of 3 spines, RES, 1 row of 3 spines; tarsus, verticellum of 6 spines. *Palpus.* Femur, EPS, 1 row of 3 spines and 4 additional spines at distal end; tibia, PRS, 2 spines, RES, 1 spine.

Color in life: Males and females of same color; cephalothorax brown with a lighter median band as broad as eye area; face and clypeus light brown; legs uniform brown; sternum with 3 pairs of dark spots; abdomen gray with 2 dark spots above in front and a median dark band underneath.

Patria: Jamaica, W. I.

I found many mature and young males and females at Malvern, Jamaica, W. I., in April and May, 1905. They live under rocks, where the females guard their large flat cocoons. The moment one sees the hand of the collector approaching, she falls on her back, spreading wide her legs and opening the mandibles. In this curious manner she evidently tries to defend herself from the attacking enemy, the position being of great advantage. At least, on approach of the forceps she grabs them at once with all her eight legs and bites fiercely into them. Whether this species is poisonous, I could not ascertain.

Collection: A. Petrunkevitch.

PISAURIDÆ.

27. **Dolomedes triton** Walckenaer (sub Lycosa), Ins. Apt., vol. i, p. 340. 1837.

= *Dolomedes sexpunctatus* Hentz et auctorum.

That the two names are synonyms can scarcely be doubted. The description given by Walckenaer corresponds exactly with the specimens which I have collected in New Jersey and other States. Walckenaer places his *D. triton* in the second family, *i. e.* Piraticæ, of which he writes on page

339 of the work cited: "Yeux dont la ligne antérieure est sensiblement plus large que la ligne intermédiaire." And on page 344 we read: "Pirates.... se rapprochent déjà du genre Dolomède." The name of "waterspider" given to the species by Abbot and his additional observations on the aquatic habits of the spider establish beyond doubt the identity of *triton* with *sexpunctatus* Hentz, which latter becomes therefore a synonym of the former.

28. **Ancylometes vulpes** Bertkau. Verz. Bras. Ar. p. 115. 1880.

Plate XXII, Fig. 35.

The following description of a specimen in my collection is with slight alterations copied from Dr. Moenkhaus's notes which he was kind enough to give me, together with his entire collection of Brazilian spiders.

Female.— Total length, 22; cephalothorax, 11.6 long, 9.5 wide in middle, 6.5 wide in front; abdomen, 11.5 long, 7.0 wide; sternum, 4.5 long, 2.5, wide.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	8.7	11.5	6.5	3.5	30.2
II	8.7	11.1	6.1	3 2	29.1
III	7.4	9.9	6.1	3 4	26 8
IV	10.0	12.7	10.6	4.2	37.5

Lower margin (retromargin — A.P.) of fang groove with 4 large, equally strong and equidistant teeth; upper margin with 3 teeth of which the middle is the largest; second row of eyes slightly procurved by their lower margin; the laterals oval, much smaller and equally removed from the median and the posterior eyes; the medians are removed by their radius from each other and from the laterals, and a little closer to the slightly smaller ones of the anterior row; quadrangle a little longer than broad, scarcely narrower in front; clypeus about twice the diameter of the anterior eyes; cephalothorax high, steep behind, straight to posterior row of eyes, from this point on slightly inclined; sides of head sloping, but steeper than sides of thorax; median groove deep anteriorly, scarcely visible posteriorly; head and radiating grooves not distinct; mandibles very strong; lip scarcely longer than broad in front, narrower toward base, its tip truncate, a transverse impression near middle; maxillæ arched, broader toward end, their outer edge straight, while their inner edge is strongly emarginate around lip; spinnerets short, the posterior pair more slender and a little longer; terminal joint short; legs very strong; tarsi and metatarsi with thick scopulæ.

Color: Entire animal tan colored; abdomen a little darker above and on sides; tarsi and metatarsi darker; mandibles dark reddish brown; lip and maxillæ a little lighter, with a still lighter edge; integuments covered with golden yellow hair; longer grayish hair on mouthparts.

Spines on legs: *First leg.*— Femur, above, 1–1–1, in front, 2 distal ones, behind, 1–1; tibia, below, 2–2–2–2; metatarsus, below, 2–2–2.

Same arrangement of spines on all legs; all tarsi with three claws; third claw simple, slightly curved; superior claws with six teeth each, the two basal teeth small and almost fused.

PATRIA: Brazil.

Two females were collected on grass in a swamp at Poco Grande, Brazil. One of them had an egg sack with one side flat and the other side rounded, light brown in color.

COLLECTION: A. Petrunkevitch.

LYCOSIDÆ.

29. **Lycosa avida** Walckenaer, Ins. Apt., vol. i. 1837.

= *L. erratica* Hentz. Journ. Bost. Soc. Nat. Hist., vol. iv, p. 388, pl. 18, fig. 8. 1844.
= *L. communis* Em. Trans. Conn. Acad. Sci., vol. vi, p. 489, pl. 47, fig. 6. 1885.

The synonymy of this species was given some time ago by Nathan Banks. Walckenaer's description corresponds fairly well with that of Emerton. This is especially true of his description of the color of the venter so characteristic in typical specimens. The great variability of this species makes it possible that Walckenaer's *L. mordax*, or at least some of its varieties, is also a synonym of *avida*, in which case the name *mordax* would have preference. But the remark on page 344 that the eyes of *mordax* remind one of Dolomedes makes such synonymy doubtful.

30. **Lycosa nychthemera** Bertkau, Verz. d. Bras. Ar., p. 68, pl. 2, fig. 21. 1880.

Plate XXII, Fig. 36.

Bertkau has described the female only. I have in my collection two females with cocoons and two males of this beautiful species. They were collected by Dr. Moenkhaus at Ypiranga, Brazil.

Female.— Total, including mandibles, 29.5; cephalothorax, 12.2 long, 9.0 broad between second and third pair of legs; abdomen, 14 long; legs in order 4123.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	9.6	11.7	7.3	4.3	32 9
II	9.0	11.0	6 8	4 2	31 0
III	8.0	9.0	6.3	3.8	27.1
IV	10.5	12.5	10.4	5.0	38.4

Arrangement of spines on legs same as in male; markings on body also same as in male, but color a little darker.

Male.— Total, 21; cephalothorax, 11.3 long, 9.0 broad between second and third pair of legs; abdomen, 10 long; legs in order 4123.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	10.0	12.5	8.6	5.5	36.6
II	9.5	11.0	7.6	4.6	32.7
III	7.5	9.5	7.5	4.3	28.8
IV	10.3	12.6	11.7	5.5	40.1

Arrangement of spines on legs exactly as described by Bertkau for the female. *L. nychthemera* belongs to that group of species of the genus *Lycosa* which has 2 spines above on tibia of fourth pair (one at base, the other about two thirds of tibial length from tibio-patellar joint). The four front legs have thick scopulæ on tarsi, metatarsi and on distal third of tibiæ; scopulæ of the 4 hind legs are less thick and extend only over tarsi and greater part of metatarsi as far as base of proximal spines.

Color in alcohol: Cephalothorax brown with a median lighter band which extends in front as far as eyes of second row; 3 pairs of light lines run from dorsal groove toward legs; abdomen grayish brown; in front a triangular mark followed by 2 brown "W" - marks and 2 transverse dark lines; legs of same color as cephalothorax, but with 2 dark lines on EPS of each femur, due to absence of pubescence; mandibles brown, lighter than cephalothorax; fang red-brown; palpi yellow; sternum, coxæ and venter black, lip and laminæ maxillaries yellow; legs underneath lighter than above; patellæ black, distal third of tibiæ also black; metatarsi and tarsi dark brown; scopulæ dark; whole appearance of *L. nychthemera* reminds one strongly of the northern *L. carolinensis.*

31. **Schizocosa crassipes** Walckenaer (sub Lycosa), Ins. Apt. i, p. 323. 1837.

= *Lycosa ocreata* Hentz et auctorum.

The synonymy of this species is more than probable. Walckenaer gives the following characteristic description of the male on page 323: "Pattes fauves, avec le tibia des jambes antérieures très renflé par "une touffe de poils noirs, dans les mâles." Both *ocreata* Hentz and *bilineata* Emerton possess this character; but the latter species is smaller than the former. It is rather rare and was only quite recently discovered and described by Montgomery, whereas *ocreata* is quite common.

Moenkhausiana gen. nov.

Frons lata, humilis; facies trapezoidalis, utrinque obliqua; oculi antici medii parvi lateralibus majores; oculi ser. 2 -ae magni, spacio oculo vix angustiore a sese distantes; oculi ser. 3 -ae remoti et cum oculis ser. 2 -ae aream latiorem quam longiorem occupantes; clypeus oculis mediis anticis vix latior; pars labialis longior quam latior; chelarum pro-margo (superior) tridentatus, dens medius reliquis major; chelarum retro-margo (inferior) dentibus trinis aequis armatus; pedes in

ordine IV–I–III–II; metatarsi postici tibia cum patella brevier; tarsi cuncti scopulati; unguis inferior muticus; mamillæ anteriores plus duplo longiores et robustiores quam mamillæ posteriores.

Typus: M. brasiliensis.

32. **Moenkhausiana brasiliensis** sp. nov.

Plate XXII, Figs. 26, 27, 28, 29.

Female.— Total length, 10.0; cephalothorax, 5.0 long, 3.7 broad; sternum and lip longer than broad; legs in order 4132.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	3.8	4 4	2.8	1.5	12.5
II	3 5	4.3	2 8	1.5	12 1
III	3.4	4.0	3 2	1 8	12 4
IV	4 2	5.9	4.4	2.3	16.8

Arrangement of spines on legs same as in male; all 8 tarsi with scopulæ; superior claws with a series of 7 teeth, inferior claw smooth; trochanters with a deep notch; palpal claw with 4 teeth; color and other characters as in male; arrangement of spines on palpus a little different, as follows: femur, EPS, 1 row of 3 spines and 2 additional distal spines; patella, PRS, 1 spine, RES, 1 spine; tibia, PRS, 2 spines; tarso-metatarsus, PRS, 3 bristles; epigynum resembles that of *pirata*.

Male.— Total length, 10.0; cephalothorax, 5.0 long, 3.8 broad between second and third legs; abdomen, 5.0 long; clypeus, 0.22; entire eye group, 1.35 long; anterior row of eyes, 0.90 wide, second row, 1.00, third row, 1.25; diameter of eyes: AM, 0.20, AL, 0.16, PM, 0.35, PL, 0.30; distance between inside edges of AM, 0.13, between the outside edge of AM and inside edge of AL, 0.08, between inside edges of PM, 0.30, between inside edges of PL (eyes of third row), 0.80, sternum, 2.5 long, 1.9 broad between second and third pair of coxæ; lip longer than broad; both margins of chelæ with three teeth; teeth of pro-margin unequal, middle tooth strongest; teeth of retro-margin are to all appearance equal; forehead low and broad, gradually sloping toward sides; trochanters of all legs with deep notch; fourth metatarsi shorter than fourth tibia and patella; all tarsi with scopulæ; superior claws with a series of 7 teeth; inferior claw smooth; tarso-metatarsus of palpus with 2 smooth claws; legs in order 4132.

Legs	Femur	Pat. + Tib.	Metatar.	Tarsus	Total
I	3 8	4.8	3 1	1.8	13.5
II	3.5	4.3	3 0	1.8	12.6
III	3.8	4.3	3 0	2 0	13.1
IV	4.3	5 8	4.2	2.2	16 5

These measurements show that both sexes are remarkably similar as to the total size of their legs. The coloration being also the same in both sexes, it is only the structure of the palpus that betrays the sex. Such similarity of sexes is rather unusual in Lycosidæ.

Spines on male palpus: femur EPS, 1 row of 3 spines and 2 additional distal spines; patella, PRS, 1 bristle.

Spines on legs in both sexes: *First leg.*— Femur, EPS, 1 row of 3 spines and 2 additional distal spines; patella, PRS, 1 spine, RES, 1 spine; tibia, HYS, 2 rows of 3 spines each, PRS, 2 spines, RES, 2 spines; metatarsus, HYS, 2 rows of 2 spines each, PRS, 2 spines, RES, 2 spines, also a distal verticellum of 5 spines. *Second leg.*— Femur, EPS, 3 rows, middle row of 3 spines, siderows of 2 spines each; patella and metatarsus same as in first leg; tibia, HYS, 2 rows of which 1 consists of 2 and the others of 3 spines, PRS, 2 spines, RES, 2 spines. *Third leg.*— Same as second leg, but tibia has besides on EPS 1 spine in middle and 1 bristle at proximal end. *Fourth leg.*— Same as first leg, but tibia has besides on EPS one spine in middle and one bristle at proximal end; the presence of the spine and of the bristle on the episyn-axial surface of the third and fourth tibia recalls spiders which F. Cambridge placed in the genus *Arctosa*; structure of male palpus (Plate XXII, fig. 29) suggests *Pirata*; spinnerets alike and very characteristic in both sexes (Plate XXII, figs. 26 and 27); anterior spinnerets when in state of full erection are three times longer than posterior ones and considerably heavier; colulus long and covered with long hair; integuments all over body and on legs are covered with two kinds of hair: long black hair and short white hair, both kinds are simple.

Color in alcohol: Cephalothorax reddish brown with narrow black marginal band and black triangular spots around dorsal groove; mandibles brown; lip and laminæ brown, but much lighter than mandibles, with light tips; sternum in one male nearly black, in the other male and in female light, with 4 pairs of black marginal spots; legs above of the same color as cephalothorax, underneath considerably lighter (coxæ included); 2 pairs of lateral black spots on all femora and tibiæ which produce the impression of dark rings, although no real ring is formed; palpi of the same color as legs, but the darker spots missing; abdomen above dark grey, with a dark lancelike mark in front, behind this mark it is mottled with yellow, and these yellow markings remind one much of those on abdomen of *Amaurobius silvestris*; venter with a dark broad band extending from genital groove to spinnerets; spinnerets light yellow.

Patria: Brazil.

Collection: A. Petrunkevitch. Two males and one female collected by Dr. Moenkhaus at Ypiranga, Brasil.

PLATE XXI.

Fig. 1. **Acanthoctenus Marshi** F. Cambridge. Epigynum.
" 2. **Orchestina saltabunda** Simon. Male palpus.
" 3. *Idem.* Side view of spider without legs.
" 4. **Melanophora rufula** Banks. Male palpus.
" 5. **Spermophora meridionalis** Hentz. Male palpus.
" 6. **Theridionexus cavernicolus** sp. nov. Male palpus.
" 7. *Idem.* Epigynum.
" 8. **Alcimosphenus bifurcatus** sp. nov. Young female.
" 9. **Micrathena horrida** Taczanovsky. Epigynum and lungs.
" 10. *Idem.* Abdomen from above.
" 11. *Idem.* Side view of abdomen.
" 12. **Micrathena oblonga** Taczanovsky. Epigynum.
" 13. *Idem.* Side view of abdomen.
" 14. **Micrathena sordida** Taczanovsky. Epigynum and lungs.
" 15. *Idem.* Side view of abdomen.
" 16. **Micrathena Vigorsii** Perty. Sternum.
" 17. *Idem.* Epigynum and lungs.
" 18. *Idem.* Abdomen from behind.
" 19. *Idem.* Side view of abdomen.

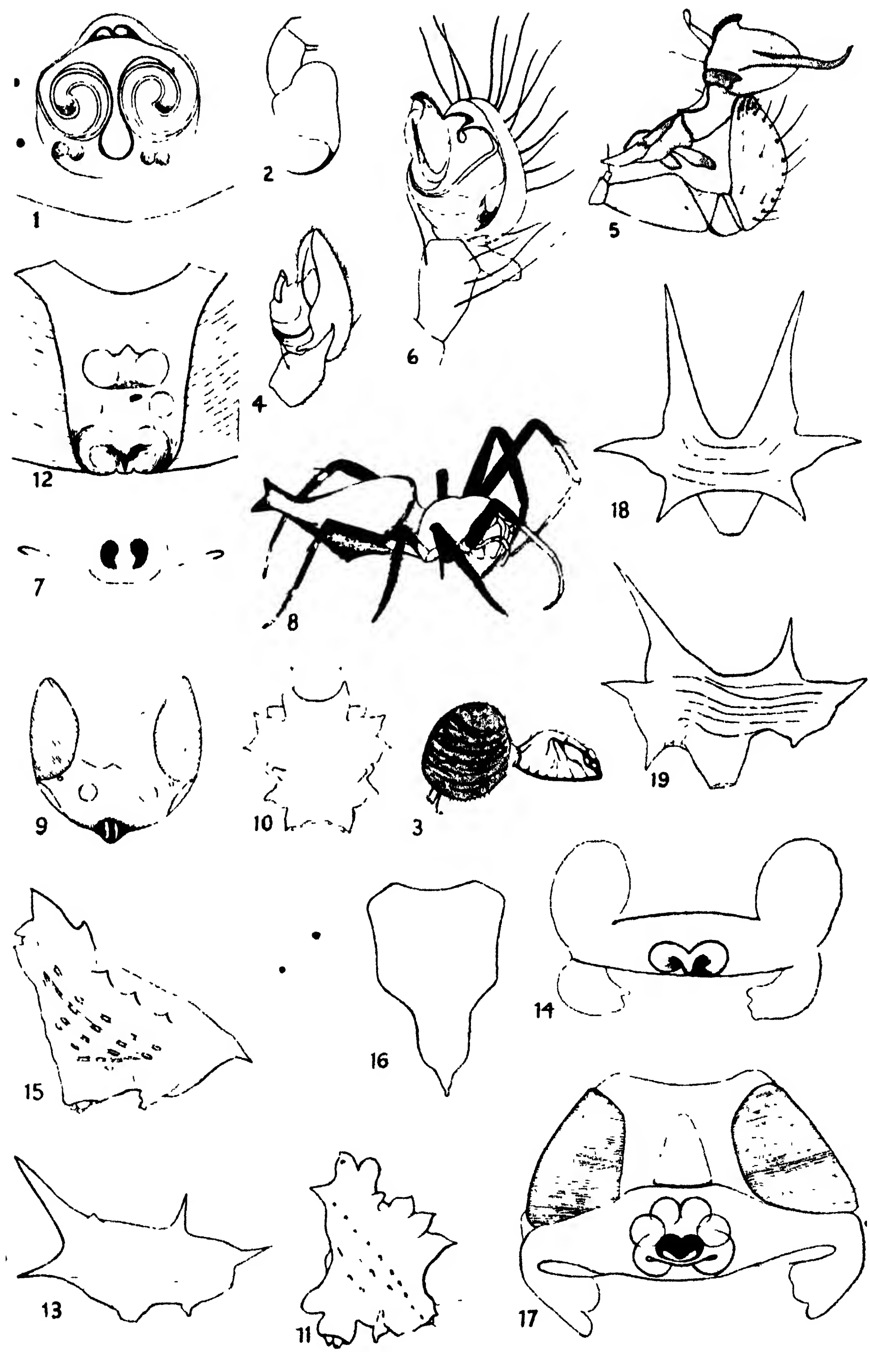
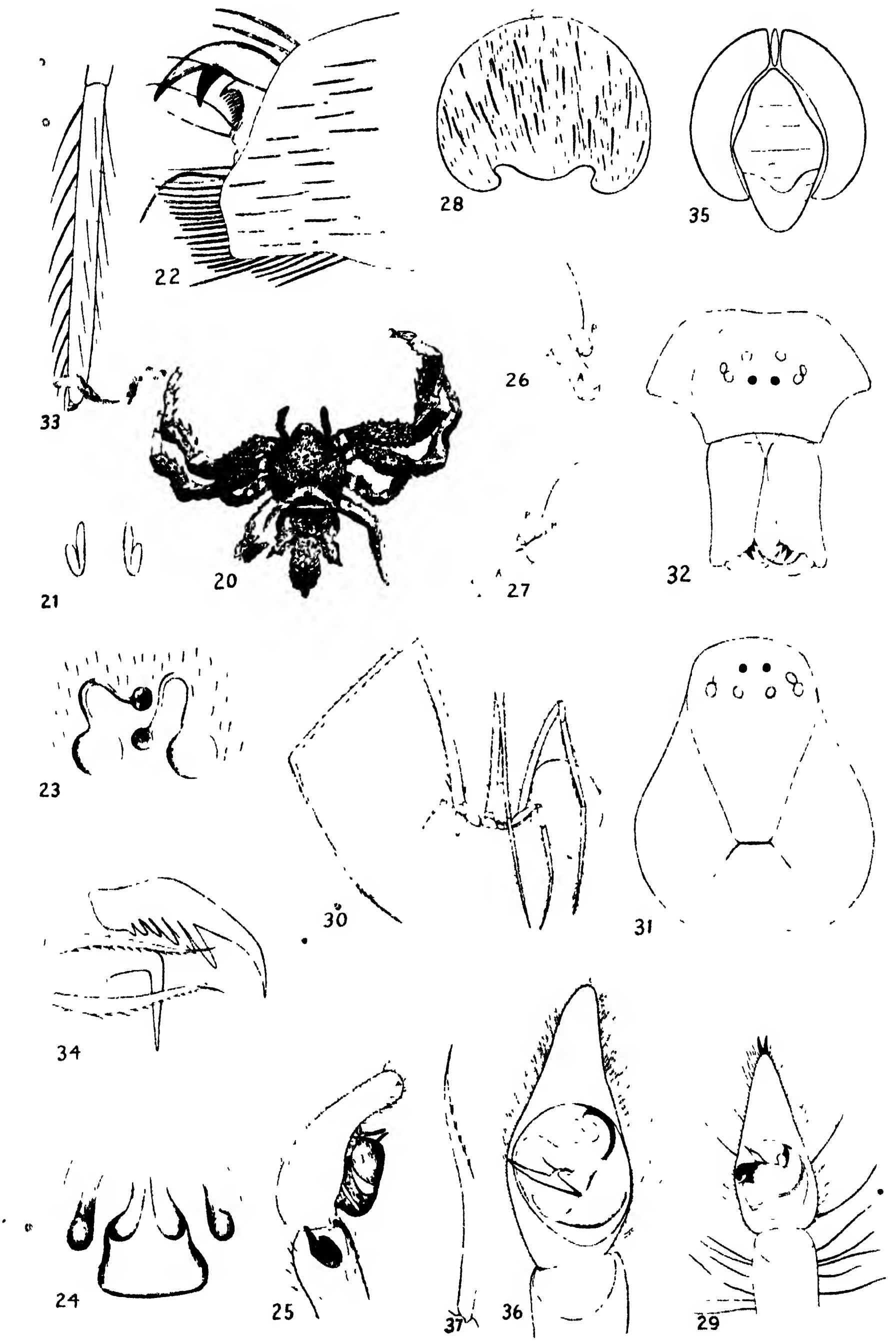

1
2
6
5
12
4
18
7
8
19
9
10
3
15
16
14
13
11
17

PLATE XXII.

Fig. 20. **Epicadinus tuberculatus** sp. nov. Adult female.
" 21. *Idem.* Epigynum.
" 22. *Idem.* End of tarsus with claws.
" 23. **Phrurolithus Britcheri** sp. nov. Epigynum.
" 24. **Ctenus malvernensis** sp. nov. Epigynum.
" 25. *Idem.* Male palpus.
" 26. **Moenkhausiana brasiliensis** sp. nov. Side view of spinnerets in state of contraction.
Fig. 27. *Idem.* Side view of spinnerets in state of expansion.
" 28. *Idem.* Epigynum.
" 29. *Idem.* Male palpus.
" 30. **Theridionexus cavernicolus** sp. nov. Adult female.
" 31. *Idem.* Cephalothorax from above.
" 32. *Idem.* Face and mandibles.
" 33. *Idem.* Fourth tarsus with comb.
" 34. *Idem.* Claws and serrate bristles.
" 35. **Ancylometes vulpes** Bertkau. Epigynum.
" 36. Lycosa nychthemera Bertkau. Male palpus.
" 37. **Theridiorexus cavernicolus.** One of the combhairs magnified.


22
33
28
35
26
32
20
21
27
23
30
31
34
24
25
37
36
29

[ANNALS N. Y. ACAD. SCI., Vol. XIX, No. 10, Part II, pp. 225–245, 18 March, 1910.]

THE FOUNDER OF THE EVOLUTION THEORY.

By CHARLES FINNEY COX.

Presidential Address, read at the Annual Meeting of the New York Academy of Sciences, December 20, 1909.

On the thirteenth of last June, I had the pleasure of attending the ceremonies connected with the dedication of a noble statue of the Chevalier de Lamarck, in the Jardins des Plantes, in Paris. The monument could not have been placed over the remains of the great naturalist, since no one knows his last resting-place. Still better, however, it was erected at the principal entrance to the botanical garden within which he lived and labored during the greater part of his long and well-filled life and where most of his descriptive and philosophical writing was done. There, before the applauding multitude, the humble student of nature, whom the artist has ably and faithfully portrayed, was acclaimed by the highest officers of state and by distinguished men of science with lofty and unstinted eulogium.

This formal recognition of Lamarck's eminence in the world of science and of his importance in the realm of systematic thought came a little tardily, perhaps, in the eightieth year after his death, but it was interesting and suggestive that this commemoration of the hundredth anniversary of the publication of his most important work should have fallen in the very month when men of learning from almost every civilized country on the globe were journeying to Cambridge to celebrate the centenary of the birth, and the fiftieth anniversary of the issuance of the epoch-making book, of that other great naturalist and philosopher whose name has been, since 1859, most often coupled with Lamarck's. This unique occasion inevitably brought to mind, with peculiar significance, a comparison of the views and theories of these two representative evolutionists, especially to those who, like myself, expected to turn from the flowery paths so long frequented by Lamarck to the stately halls and peaceful "quads" familiar to the college days of Darwin. As a good Darwinian, I was glad of the privilege of paying my silent tribute of respect to the famous author of the "Philosophie Zoologique," but, in view of the later object of my pilgrimage, I was not in a mood to yield, out of mere courtesy and momentary enthusiasm, any of my long cherished loyalty to the writer of "The Origin of Species." It was,

therefore, with surprise and regret that I observed upon the pedestal of Lamarck's statue an inscription describing him as the founder of the theory of evolution. Instantly I registered a mental protest and, ever since, I have wished for the opportunity to give my protest oral expression, which I must now do.

To my mind, a person can be said to have founded something only when he has either originated it or, finding it already existing in a state of instability, has supplied it with the immovable basis which it lacked. Now, it is not claimed, I believe, by any one that Lamarck first conceived and propounded the general theory of evolution. On the contrary, it is well understood that the idea of derivation and progressive development has been set forth, more or less explicitly, by numerous philosophers from at least the early days of Greek literature down to Lamarck's own time and that even the form of the doctrine which he himself expounded was in its essential substance advocated by his immediate predecessors, Buffon and Erasmus Darwin. Those, therefore, who look upon Lamarck as "the founder of the evolution theory" must believe, not only that he first placed under the ancient conception of derivation a solid groundwork of irrefragable argument or proof, but that he also gained for it some considerable degree of acceptance by those best able to pass upon its claims. But this he did not do.

Whatever we may now think of the value and validity of the Lamarckian factors of evolution, we must admit that during his lifetime and for not less than thirty years after his death Lamarck's philosophical views attracted little attention and made no great impression upon the learned world. I cannot think of a single eminent man of science who championed Lamarck's particular theory of variation until after Darwin had given new life to the whole subject of evolution, unless we are to admit that Herbert Spencer's views, expressed in 1852 in his "Essay on the Development Hypothesis", were an echo from Lamarck's writings, which I think is very doubtful. Geoffroy St. Hilaire and a few others, it is true, mildly pronounced in favor of the mutability of species though not attributing it distinctly to the causes assigned by Lamarck, but it is safe to say that during the first half of the nineteenth century the dogma of special creation was as firmly intrenched and as generally accepted as if Lamarck had never lived. Even when Lyell and Hooker presented the joint paper of Darwin and Wallace to the Linnæan Society, on the first of July, 1858, the matter practically fell flat. Lyell himself was not convinced of the mutability of species until years afterwards, and it was only when "The Origin" appeared, in November, 1859, that the world awaked to a realization of the fact that the evolution theory had to be reckoned with; and the scientific part of the world aroused itself no more quickly than the rest. August Weismann says, "We who

were then the younger men, studying in the fifties, had no idea that a theory of evolution had ever been put forward, for no one spoke of it to us, and it was never mentioned in a lecture." He also declares that "Darwin's book fell like a bolt from the blue; it was eagerly devoured, and while it excited in the minds of the younger students delight and enthusiasm, it aroused among the older naturalists anything from cool aversion to violent opposition." [1]

Darwin knew that when he should publish his denial of the separate and definitive creation of each particular species, he would have to face a nearly unanimous adverse judgment, among the learned and the unlearned alike. His feeling in this matter was shown by his half-humorous remark, when announcing to Joseph Hooker, in 1844, his conviction as to the transformation of species, that he felt as if he were confessing to a murder! And this was only fifteen years after the death of Lamarck. It is indicated also by his writing to Asa Gray, in 1856, "As an honest man I must tell you that I have come to the heterodox conclusion that there are no such things as independently created species,— that species are only strongly defined varieties. I know this will make you despise me." [2] Darwin underestimated Gray's preparedness to receive the new doctrine, but he showed that he did not expect a respectful hearing for his novel ideas by men of science generally, and in this unfavorable prognostication he proved to be right. Hooker, Gray and Wallace were his only staunch allies at first; but Huxley joined the little band soon after the opening of the war, although he never gladdened Darwin's heart by unreservedly accepting natural selection. Lyell, of all Darwin's personal friends, gave him the greatest grief by his hesitation, especially because he seemed in private more favorable than he was willing to appear in public. Worst of all, he confessed to Huxley that he was held back more by his feelings than by his judgment. His final surrender was made in the tenth edition of his "Principles of Geology," published in 1869.

For fully ten years, then, Darwin was obliged to plead with his scientific acquaintances to come even a little way with him, assuring them that if they would only admit the mutability of species, he would not urge them to go the length of accepting natural selection,— thus proving that the scientific world had by no means been led up to a recognition of the fact of transmutation, much less to the reception of any particular theory of its causation. Even as late as 1880 we find Huxley apologizing to Darwin for having slighted or ignored natural selection in his lecture on "The Coming of Age of the Origin of Species," because, as he argued, it was

[1] "The Evolution Theory," Thomson's translation, p. 28. 1904.

[2] "Life and Letters of Charles Darwin," Vol. II, p. 79. 1887.

still essential "to drive the fact of evolution into people's heads" leaving the exposition of its cause, or *modus operandi*, to come later.

But English men of science were not alone in their reluctance to adopt the evolution theory. As Huxley said, "Germany took time to consider." Bronn produced a poor translation of "The Origin" in 1860, but omitted from it, out of deference to popular opinion, numerous supposedly offensive passages (as, for example, the sentence near the end concerning the light likely to be thrown upon the origin of man) and added a critical appendix intended to expose Darwin's weak points and to soften the effect of some of his scientific heresies. Although Ernst Krause attributes considerable influence to Hackel's advocacy of evolution in his "Radiolaria" published in 1862, he says it was really in 1863, when Häckel championed the cause at the "Versammlung" of naturalists at Stettin, that the Darwinian question could be considered as having been placed "for the first time publicly before the forum of German science." In France, according to Huxley, the ill-will of powerful members of the Institute "produced for a long time the effect of a conspiracy of silence," and it was only in 1869 that Hooker was able to say, "the evolution of species must at last be spreading in France." Looking at the whole situation a year after the publication of "The Origin," Huxley says that the supporters of Mr. Darwin's views were numerically extremely insignificant and that "there is not the slightest doubt that, if a general council of the Church scientific had been held at that time, we should have been condemned by an overwhelming majority." [1] In this connection it needs to be remembered that it was not simply the concept of natural selection or any other peculiarly Darwinian idea against which the vote of the overwhelming majority would have been cast, but that it was the general subject of transmutation and adaptive development towards which nearly the whole world was unreceptive and unfriendly. Now, if this is a true statement of the case, how can it be said that Lamarck had founded the theory of evolution? Even if Lamarck and Darwin had held exactly the same beliefs, there would be no more reason for asserting that Lamarck had set those beliefs upon a sure foundation than for saying that Wells or Matthew or Wallace had established the doctrine of natural selection before its exposition by Darwin.

That Lamarck had made an earnest and creditable attempt to provide the development hypothesis with a sound basis is not to be denied, and we may willingly concede that his effort was properly directed towards the establishment of a reasonable explanation of variation, but it is beyond question that Lamarck did not succeed in convincing his contemporaries

[1] "On the Reception of the 'Origin of Species,'" in "Life and Letters of Charles Darwin," Vol. II, p. 186. 1887.

that his explanation was the correct one and that no considerable number of competent judges have pronounced in his favor from his day until this. If he had been fortunate enough to accomplish the object he had in view, he would have supplied the evolutionary process with a starting-place one step further back than the point at which Darwin was obliged to begin; for even the most thorough-going Darwinian must in justice admit that it is a fair criticism which has been often brought against Darwin's philosophical scheme that, while it made much of the survival of the fittest, it offered no satisfactory clue to the origin of the fit. Although Darwin wrote an extensive treatise on "The Variation of Animals and Plants Under Domestication," and included in "The Origin" a carefully composed chapter on the causes of variation in general, he never really convinced even himself as to how differences of form and function arose, but was obliged, after all, to assume their origin through the operation of some inscrutable law, availing, however, to some extent, of the influence of external conditions as an excitant to its action. On the other hand, Lamarck did not fully realize the extent and intensity of the struggle for existence and had little idea of the potency of selection; for, under his scheme, all positive variations must be useful from the beginning, since they arise solely in response to needs, and there is no necessary sifting out of good, better and best, except in the respect that whatever is not wanted retrogrades and disappears by the way it came.

Lamarck's four laws, as given in the introduction to his "Animaux sans Vertèbres," are as follows:

"First: Life, by its proper forces, continually tends to increase the volume of every body which possesses it and to increase the size of its parts, up to a limit which it brings about.

"Second: The production of a new organ in an animal body results from the supervention of a new want which continues to make itself felt, and of a new movement which this want gives rise to and maintains.

"Third: The development of organs and their power of action are constantly in ratio to the employment of these organs.

"Fourth: Everything which has been acquired, impressed upon, or changed in the organization of individuals during the course of their life is preserved by generation and transmitted to the new individuals which have descended from those which have undergone those changes." [1]

I venture to think that these laws must sound archaic to any reader of the present day and that, as a whole, they appeal to the judgment of few workers in science of our time as an adequate evolutionary scheme. Compared with Darwin's logical sequence of the six factors, Variation, Heredity, Over-

[1] Translation by A. S. Packard, in "Lamarck the Founder of Evolution," p. 346. 1901.

reproduction, Competition, Adaptation and Selection and Survival, Lamarck's loose arrangement of his four factors, Growth, Response to Needs, Effects of Use and Disuse and the Inheritance of Acquired Characters, can not but seem weak and inconclusive, particularly when we remember that for the vegetable kingdom Lamarck was obliged to fall back upon Buffon's factor, the Direct Action of the Environment, while Darwin's closely-knit argument was applicable to the entire living world. Of course Lamarck never could have known how utterly inadequate his system was to explain variations in floral structures through which they are adapted to fertilization by insect agency, or to account for protective coloration and mimicry among animals.

Cuvier is said to have killed Lamarckism by his ridicule of it, but Darwinism was born with a stronger constitution, for it has survived many times the amount of sarcasm and contempt that were aimed at Lamarck's philosophy. Lamarck's times were undoubtedly unfavorable to a fair examination of his ideas. Fifty years later, however, Darwin not only conquered a hearing for his own theories, but actually opened the way for a just consideration of Lamarck's. It is often said that Darwin succeeded because the times were ripe for the acceptance of the evolution theory when he appeared as its advocate; but Darwin himself denied this, and I am at a loss to understand how such an opinion can be entertained in face of the plain history of the subject to which I have referred and which shows that Darwin gained his adherents one by one, and only by much argument and persuasion, during at least a decade following the publication of "The Origin of Species." Lamarck did not fail because of Cuvier's ridicule, and Darwin did not prevail because the time of his appearance was opportune as to the trend of philosophical and scientific opinion. Darwin created his own opportunity by long years of preparatory work and forced the issue by the final presentation of a convincing chain of reasoning, underlain by his discovery of an efficient cause of progressive development. Professor Osborn[1] has correctly and strikingly summarized the causes of Darwin's ability "to leap along over the progress of centuries" as (1) his patience and caution, (2) his diligence in seeking "a hundred facts and observations where his predecessors sought one," he standing out as the first evolutionist who worked "upon true Baconian principles," (3) his originality, (4) his good fortune in having "lived at a time when the storehouse of facts was fairly bursting for want of a generalization" and (5) the effects of "the training he got as an observer on the Beagle voyage."

Unlike the "Philosophie Zoologique," "The Origin of Species" was

[1] "From the Greeks to Darwin," pp. 230–231. 1908.

truly an epoch-making work. It instantly commanded respect and demanded attention. Coming, however, as I have shown, without having had its way prepared for it, it was not to be expected that it would immediately secure general acceptance. Even men of trained intellect pronounced it a difficult book to digest, but as fast as competent critics mastered its significance it conquered the judgment and compelled assent as no other work of scientific philosophy has ever done. Its influence has been cumulative down to our own day, and, although it is not read as much as it was twenty or thirty years ago and is even believed by a few to be out of date as a guide to investigation and thought, its spirit permeates all scientific work of any value, and the trails it blazed across the barren wastes of ignorance have become the broad roads of modern research. Some who are fortunate enough to have opened up side paths of investigation are wont to forget their obligation to the pioneer work which made possible the highway of wisdom from which they have diverged in pursuit of their specialities, but the broad-minded historian of science can never fail to accord to Darwin the credit due him as an explorer and discoverer in regions previously inaccessible and *incognita*.

I have no wish to belittle the work of Lamarck. His was one of the courageous voyages out onto the sea of speculation which whetted men's appetite for a larger and completer expedition into the region of the unknown. Lamarck touched upon some of the outlying islands of the new world of knowledge, but Darwin penetrated into the interior and brought back a map upon which investigators are still obliged to rely. To drop metaphor, Lamarck's methods were somewhat academic and almost purely deductive and were therefore unsatisfactory to the strictly logical mind. Moreover, as has been said by Professor Osborn,[1] his "crude illustrations certainly could not predispose his contemporaries in favor of his theory." Darwin, on the other hand, according to John Stuart Mill, employed reasoning which was "in the most exact accordance with strict principles of logic," and he supported his theory by an appeal to a vast array of facts which it connected and explained. Darwin's argument as a whole was clear-cut and focused upon a coherent line of thought, while Lamarck's was often faltering and inconsistent. It is hard to decide, for instance, whether Lamarck believed that the evolutionary process was dependent entirely upon the operation of natural laws, or that there was occasional supernatural intervention by a creational and directive power, or that the Creator merely started the universe with a set of general principles and then left it, like Babbage's "calculating engine," to turn out its own progressions.[2] It is possible, however,

[1] *Op. cit.* p. 170.
[2] See "The Ninth Bridgewater Treatise," 2d ed., Chap. VIII. 1838.

that this uncertainty of expression was an intentional concession to the theological bias of his time.

Upon examining Lamarck's four laws and their context it does not appear that he offered any really characteristic or original addition to the ancient philosophy of progressive development except the idea contained in the second law that "the production of a new organ in an animal body results from the supervention of a new want"; but even if he had succeeded in proving that when an organ is needed it will forthwith make its appearance or be brought into existence by a new movement which the want gives rise to, he would not have done much towards simplifying the problem of evolution, for he would have given us no reason why every form that has ever existed was not fitted to leave an unbroken line of descendants. The feeling that Lamarck's attempted explanation of the origin of organization did not really explain is the most powerful reason why his whole philosophy has been rejected by the great mass of scientific workers and thinkers. His first law, as to the cause and the limitation of growth, and his third, as to the effect of use upon the development of organs, state facts so obvious and so long understood that they amount to little more than truisms. His fourth law, referring to what is commonly called the inheritance of acquired characters, like his second law, is generally discredited by working naturalists, but I confess I am not quite able to appreciate the ground of its unqualified rejection. But since it actually is discredited, together with the only other law that was distinctly Lamarckian, I can not help asking once more for the foundation of the evolution theory which is said to have been laid by Lamarck.

Lamarck, of course, believed in the transformation of species, in some form, as he was obliged to do as a professed evolutionist, although Darwin, with unusual bluntness, spoke of his views on mutability as "veritable rubbish."[1] But like other evolutionists Lamarck needed to account for the transmission of variational effects, and it seems to me he was at least logical in deeming his fourth law a necessary part of his system, although I think he might better have made it a little less absolute than it is made by the statement that "everything which has been acquired" is transmitted. Darwin followed Lamarck in his general idea of the inheritance of acquired characters, and I do not see how he could well have avoided doing so, for, with Lamarck, he appears to have thought that if any organic form is like a parent but unlike any grandparent, it has inherited something that was acquired by the parent. Parenthetically, I wish to remark, that I doubt whether in his fourth law, Lamarck used the word "acquired" in any such narrow sense as that given to it by controversialists of the present day. It is

[1] "Life and Letters," Vol. II, p. 29. 1887.

altogether probable that by an "acquired character" he meant merely any new character brought into existence in adaptation to a new demand made upon an animal by a change in its environment. Neither he nor Darwin knew of the fine distinctions now made between a quality inherent in the germ-plasm and a characteristic originating in the soma. Darwin, however, conceived of two kinds of variation, the one the result of conditions acting "directly on the whole organization or on certain parts alone," and the other due to influences indirectly affecting the reproductive system.[1] He was also aware of Weismann's earlier and less specific objections to the inheritance of characteristics acquired through the soma, but does not seem to have accorded them great weight, since he argues strongly for the hereditary transmission of the effects of changed habits in both animals and plants. He naturally did not like to exclude all such effects from the evolutionary process, for he held that "a variation which is not inherited throws no light on the derivation of species."[2] He says: "When a new character arises, whatever its nature may be, it generally tends to be inherited, at least in a temporary and sometimes in a most persistent manner."[3] A little later he expresses the conclusion that "the real subject of surprise is, as Sir H. Holland has well remarked, not that a character should be inherited, but that any should ever fail to be inherited."[4]

With reference to the conception of a species as a classificatory group, possibly Lamarck was somewhat more definite than Darwin, for Lamarck did propound a definition of species which is considered a good one, while Darwin carefully avoided making such a definition. It is truly remarkable, —and it is no disparagement of Darwin to concede it — that he who did more than all others to elucidate the whole subject of the origin, modification and transmutation of species should have felt himself unable to designate precisely the subject of his inquiries. Writing to Joseph D. Hooker, in December, 1856, he said: "It is really laughable to see what different ideas are prominent in various naturalists' minds when they speak of 'species'; in some, resemblance is everything and descent of little weight; — in some, resemblance seems to go for nothing and Creation the reigning idea,— in some, descent is the key,— in some, sterility an unfailing test, with others it is not worth a farthing. It all comes, I believe, from trying to define the undefinable."[5] In an earlier letter in the same year, referring to his work on the Cirripedes, he wrote: "I know in my own case my most frequent source of doubt was whether others would not think this or that was a God-

[1] "Origin of Species," 6th ed., p. 5. 1882.

[2] "Animals and Plants Under Domestication," 1st ed., Vol. II, p. 1. 1868.

[3] *Ibid.*, p. 2.

[4] *Ibid.*, p. 2.

[5] "Life and Letters," Vol. II, p. 88. 1887.

created Barnacle, and surely deserved a name. Otherwise I should only have thought whether the amount of difference and permanence was sufficient to justify a name."[1] Still earlier he confided to Hooker that after describing a set of forms as distinct species, tearing up his manuscript and making them one species, tearing that up and making them separate, and then making them one again, he had gnashed his teeth, cursed species and asked what sin he had committed to be so punished.[2] The general situation of the nomenclature question was subsequently hit off by Darwin, in a letter written to Asa Gray, November 29, 1859, in which he says: "By the way, I met the other day Phillips, the paleontologist, and he asked me, 'How do you define a species?' I answered, 'I cannot,' whereupon he said 'At last I have found out the only true definition,— any form which has ever had a specific name!'"[3] Darwin apparently rested in the position indicated by this playful allusion, and neither he nor Lamarck did much towards clearing up the subject of classification. They really left the matter in the unsatisfactory condition in which they found it, so that we of to-day are floundering in the "Slough of Despond" which entangled them and their predecessors, and our method of grouping and naming remains the most unscientific thing in the scientific world.

It is only just to observe that Lamarck, while dealing with the species question more seriously than did Darwin, was after all of Darwin's opinion as to the ultimate inconclusiveness of all attempts at exact definition. He declared that naturalists of his day were extremely troubled to say exactly what they meant by a species and gave it as his own decision that "the farther we advance in the knowledge of the different organized bodies with which almost every part of the surface of the globe is covered, the more does our embarrassment increase in determining what should be regarded as species, and the greater is the reason for limiting and distinguishing the genera."[4]

Now, although Darwin treated with ridicule the troubles of the species makers, he certainly dealt with species in all his own work as if they were necessary units in the evolutionary process; and while Lamarck, different from Darwin, was not afraid to formulate a definition of species in face of the acknowledged difficulties of the matter, it is very doubtful if he regarded them, as much as Darwin did, as the direct objects of the evolutionary forces. In 1802 he wrote: "I have for a long time thought that species were constant in nature and that they were constituted by the individuals which belong to,

[1] "Life and Letters," Vol. II, p. 81. 1887.
[2] *Ibid.*, p. 40.
[3] "More Letters," Vol. I, p. 127. 1903.
[4] A. S. Packard, "Lamarck the Founder of Evolution," p. 263. 1901.

each of them. I am now convinced that I was in error in this respect, and that in reality only individuals exist in nature."[1] This I take to mean that he formerly thought species were the units and immutable but that now he considers the unit to be the individual and species to be a convenient formula for instable and somewhat indefinite groups. He speaks in another place of Nature's causing individuals to acquire or lose their qualities by the influences of environment, by the predominant employment of certain organs or the continued lack of use of some parts. He frequently dwells on the preëminent importance of the individual in the evolutionary process and leads one to believe that this process is not operative beyond the limits of the groups called species, genera, etc.; that is to say, it is not clear from his writings that he regarded evolution as brought about by the actual transmutation of species, genera, etc., one into another. While he recognizes "a series of groups forming a true chain" and "a shaded gradation in the complication of structure," he explains that he does not mean to speak of a linear and regular series of species or even genera, for, as he declares, "such a series does not exist." But finally, he appears to have adopted the idea of the animal kingdom as constituting "a branching series," and it is claimed for him that he was the first "to sketch out a genealogical tree." The word sketch is quite strong enough to describe his action, for on this point, as on many others, he offered bare suggestions or hints without entering enough into detail to show that he had thought the subject out to a definite conclusion, as Darwin did subsequently.

The whole problem of the transformation of species rests upon the question of the origin of adaptive variations, and, notwithstanding Lamarck's attempt to account for variation by the compelling influence of the environment, and notwithstanding all the research which has been directed towards the solution of this problem since Lamarck's day, "the question of how the straight line of exact hereditary repetition may be caused to swerve in a definite direction to reach an adaptive point" remains, as Professor Eigenmann has remarked, "the question of the present generation, perhaps of the entire twentieth century."[2]

Although neither Lamarck nor Darwin settled this question, the different ways in which they dealt with it is a point of departure for their two systems. While it is true that Lamarck made no attempt to follow up the primary causes of variation to the internal organization of the individual, he did believe that external conditions were capable of exciting variability in an organism so that, through its response to the demands made upon it by its environment, what must needs be would be. Darwin, on the contrary, held that variation was, as far as human insight could go in his day, fortuitous,

[1] A. S. Packard. "Lamarck the Founder of Evolution," p. 249. 1901.
[2] Essay on "Adaptation," in "Fifty Years of Darwinism," p. 191. 1909.

though he was inclined to admit that it might be induced to some extent by the action of what he called the conditions of life.

Wallace has well set forth Darwin's point of view concerning the general nature of variation, as to which he says: "that variation is always present in ample amount; that it exists in all parts and organs; that these vary, for the most part, independently, so that any required combination of variations can be secured; and finally that all variation is necessarily either in excess or defect of the mean condition, and that, consequently, the right or favourable variations are so frequently present that the unerring power of natural selection never wants materials to work upon." [1]

Darwin, however, as I have before remarked, for the purposes of his philosophy, assumed variation as a starting-point without offering a distinct explanation of it, and in this attitude he has been justified by the negative results obtained by the latest research. But he insisted as strongly as he could that if, according to Lamarck, "the right variations occurred, and no others, natural selection would be superfluous," [2] and, of course his system could then claim no great superiority over Lamarck's. It seems almost self-evident to us now that if there are other than useful variations, or other than useful parts, or if there are variations or organs either more or less useful, natural selection must be the factor to determine the survival of the fit, or adapted, and the extermination of the unfit, or unadapted. As Darwin says in effect, selection is dispensed with only if development follows lines of variation which are pre-determined or inevitable, as it practically does from the Lamarckian point of view. There was, therefore, a radical difference between the final position assumed by Darwin and the ground occupied by Lamarck in his second law, though Darwin seems to have agreed with Lamarck, sometimes more and sometimes less, on unessential points.

One of the few subjects on which Darwin may be said to have been "touchy," particularly in later years, was the imputation to him of Neo-Lamarckian beliefs. Lyell incautiously wrote to him of "Lamarck's views improved by yours," and made a similar reference in the first edition of his work on "The Antiquity of Man," which brought out the following protest from Darwin, in a letter dated March 12, 1863:

You refer repeatedly to my views as a modification of Lamarck's doctrine of development and progression. If this is your deliberate opinion there is nothing to be said, but it does not seem so to me. Plato, Buffon, my grandfather before Lamarck and others propounded the *obvious* view that if species were not created separately they must have descended from other species, and I can see nothing else in common between the "Origin" and Lamarck.[3]

---

[1] "Darwinism," p. 424. 1889.
[2] "Life and Letters," Vol. III, p. 85. 1887.
[3] *Ibid.*, p. 14.

I am inclined to think that at first Darwin was much more of a Lamarckian than he himself realized and that he became less and less like Lamarck as years passed on. It is likely that he derived most of his knowledge of Lamarck from the two chapters devoted to him in the first edition of Lyell's "Principles of Geology,"— a book which made a greater impression upon him than was ever made by any other work,— and he admits, in his autobiography, that the hearing rather early in life the views of his grandfather, as set forth in the "Zoönomia," which were similar to the ideas afterwards advocated by Lamarck, may have favored his upholding them under a different form in his "Origin of Species." As an amusing example of such Lamarckian ideas, we may take the "wretched polar-bear case," as Darwin afterwards called it, which he dropped, rather unwillingly, from the second edition of "The Origin" upon the advice of Lyell. It was given in the first edition in the following words:

> In North America the black bear was seen by Hearne swimming for hours with widely open mouth, thus catching, like a whale, insects in the water. Even in so extreme a case as this, if the supply of insects were constant, and if better adapted competitors did not already exist in the country, I can see no difficulty in a race of bears being rendered, by natural selection, more and more aquatic in their structure and habits with larger and larger mouths, till a creature was produced as monstrous as a whale.[1]

The omission of this illustration was urged by Lyell not so much because he thought it too Lamarckian as because he doubted the truth of the statement made by Hearne, and it is probable that Darwin himself did not perceive how Lamarckian his presentation of the case was. But notwithstanding his reference to natural selection as the cause of the supposed modification of the bear, it is hard to see wherein this example is essentially less Lamarckian than the familiar one of the giraffe lengthening its neck through its efforts to reach the tops of trees, or the following example cited by Lamarck in his "Système des Animaux sans Vertèbres":

> The shore bird, which does not care to swim, but which, however, is obliged to approach the water to obtain its prey, will be continually in danger of sinking in the mud, but wishing to act so that its body shall not fall into the liquid, it will contract the habit of extending and lengthening its feet. Hence it will result in the generations of these birds which continue to live in this manner, that the individuals will find themselves raised as if on stilts, on long naked feet; namely, denuded of feathers up to and often above the thighs.[2]

In all three of the cases cited, namely, of the bear, the giraffe and the bird, it at once occurs to us to inquire as to the condition of the animal before

---

[1] "Origin of Species," 1st. ed., p. 184 1859.
[2] A. S. Packard, "Lamarck the Founder of Evolution," p. 234. 1901.

it fully attained to the ability to secure its new food supply. Professor Huxley, moved by the same impulse, asks "how long an animal is likely to endeavour to gratify an impossible desire," and concludes that "the bird, in our example, would surely have renounced fish dinners long before it had produced the least effect on leg or neck."[1] As to the polar-bear case, I trust it will not be taken as typical of Darwin's conception of the mode of origin of adapted forms in the evolution of new species. I have quoted it for the purpose of giving Lamarck full credit for whatever influence he may have exerted upon Darwin's earlier views, but in justice to Darwin we must remember that he never again conceded so much importance to the effects of mere effort in the modification of organs under the stimulus of novel conditions of life. If he had rewritten the description of Hearne's bear we may be sure that he would have ascribed quite different degrees of importance to the selection of food by an unadapted animal to suit its own tastes or desires and the selection of an adapted animal itself, through the forces of nature, to meet the requirements of a new state of the environment.

Lamarckians are apt to feel displeased when Darwinians affirm that Lamarck believed that animals developed organs by merely wishing for them, but in respect to both the wading bird and the giraffe it comes practically to the same result, if the giraffe acquired its elongated neck and the bird attained to stilt-like legs through wishing for food which was previously out of reach. What we may with fairness call Darwin's giraffe, having a normally long neck, or one normally inclined to become long, was prepared before-hand for any diminution that might occur in the supply of low-growing fodder, and its survival, after such diminution had set in or become severe, is therefore easily accounted for. We may assume that it simply applied its extraordinary length of neck to the purpose to which it was already fitted, and thus by cropping higher and higher foliage it easily acquired a monopoly of that kind of food and consequently triumphed over its short-necked companions. But what we may distinguish as Lamarck's giraffe is not supposed to have been endowed with a long neck in advance of any absolute need for such an organ, and we may therefore imagine that, when herbage began to give out, the animal must have been taken by surprise and that its circumstances must have been — as Professor Huxley has intimated that they were in the instance of the wading bird — decidedly uncomfortable and threatening unless, perchance, like the wind that is said to be tempered to the shorn lamb, the disappearance of the herbage was somehow graduated exactly to match the development of the giraffe's ability to add to the length of its cervical vertebræ. In the case of the Lamarckian giraffe, there could

[1] Essay on "The Darwinian Hypothesis," in "Darwiniana," p. 13. 1902.

have been no great competition with other kinds of animals for, as we are to suppose that those inhabiting the same region were modified in the same way by the same conditions of life, it would seem that they ought all to have gotten along equally well. Their struggle for existence was mainly against lifeless Nature and not much with living competitors, since Lamarck's law takes no account of so-called "chance" variations which may be availed of when they happen to be advantageous and which thus become the objects of natural selection. As I have already said, Lamarckism is, in its essence, a philosophy of "determinate evolution."

Now, as Professor Huxley has remarked, "for the notion that every organism has been created as it is and launched straight at a purpose, Mr. Darwin substitutes the conception of something which may fairly be termed a method of trial and error." Darwin, however, always recognized a serious difficulty in the matter of estimating the "selection value" of nascent organs, and it was at this point that St. George Mivart made his vigorous attack upon the doctrine of natural selection, which caused Darwin great uneasiness. But, having committed himself to the notion that natural selection can operate only upon minute or "insensible" gradations, Darwin was forced into a rather radical position by Mivart's somewhat effective assault. On the whole, however, his theory of natural selection was calculated to get along better with nascent organs than it seems possible for Lamarck's second law to do, for Darwin's hypothesis assumes favorable variations to begin with, which, it is easy to show, are bound to occur out of an infinite diversity of fortuitous changes, while Lamarck's law presupposes the occurrence of external conditions compelling favorable changes in the organism, and it is easy to see that there is a better chance of finding a needed form in an existing collection of endless variety than of evolving such a form on demand and in a life-and-death emergency. While it is true that Darwin was at times disposed to fall into Lamarckian modes of thought and that he wavered somewhat concerning the importance of the action of the environment and the evolutional value of use and disuse, there can be no doubt that, in its essential character, Darwin's philosophy became in the end as original and distinctive as it was consistent and convincing,—not wholly in its presentation of new points of view, but largely in its reärrangement of old points so as to cause new light to fall upon them and to set them forth in brilliant relief before the world.

The times when Darwin relapsed into Lamarckism were those moments of intellectual fatigue in which he permitted his mind to entertain the notion that natural selection was a cause of variation. On such occasions he realized that at least it could not be the sole cause, and then it was that he turned to the influence of the conditions of life and, by a curious transposition

of thought, attributed to that influence a potent evolutionary effect. If, as I pointed out in my presidential address of last year, he had persistently maintained the position that natural selection could and would operate upon any kind or degree of variation, he need not to have felt troubled as to its sufficiency as a true cause of evolution. Assuming that the action of the environment can bring about diversity of characters or qualities, the determination of the survival of the fittest under any given circumstances does not depend upon the way in which the diverse forms arose. In this matter Darwin held a much stronger position than Lamarck, for, as I have already said, Lamarck, after attempting an explanation of the origin of variation, had no means of showing why a group of organisms varying in a certain direction should be perpetuated to the exclusion of other forms which, as far as his theory provided ground for a judgment, ought, under the same conditions, to vary in the same direction and thus to acquire the same means of meeting adverse circumstances.

It is not necessary in order to maintain the supremacy of Darwin as the establisher of the evolution theory to contend that he and Lamarck had no ideas in common. They were both under the necessity of making use of the facts of nature as they were respectively able to discover them, and it would have been more than strange if, as working naturalists, they had not had common knowledge of many generalizations which were obviously important in any argument for evolution. The differences between them, upon which we are obliged to found our judgment of their relative merits, are not so much in the mere employment of certain factors as in the emphasis laid upon them and the positions given them in the general logical scheme, although, in the final analysis, it will appear that Darwin's introduction of the fascinating and satisfying doctrine of natural selection and its extension to the vegetable kingdom was the weight that turned the scales of opinion towards the acceptance of a theory of universal evolution. As I have already said, Lamarck could not have been an evolutionist without believing in the mutability of species, in some form, but he did not convince the world of the truth of mutability, because he was unable to point to its real cause. He refers occasionally to the selection practiced by breeders as evidence that variation may minister to need but fails to carry the process over into nature as a factor in general evolution. He was aware that because animals devour one another, the largest and strongest destroy the smaller and the weaker, but he never fully grasped the significance of the survival of those species best fitted to their conditions of life, nor had he the faintest idea that struggle for existence and selection of the best adapted might be the basis of evolution in the plant world. This fact we must not lose sight of, for, whatever Lamarck may have founded, according to the claims of his adherents, he cer-

tainly did not found a unified theory of evolution applicable to the whole animate world. As to animals, Lamarck appears to have attained to the point of view of Malthus, but Darwin took the Malthusian principle for a starting-place and developed his theory of natural selection from that basis to cover every form of living thing.

Lamarck appears to have believed, as Darwin did afterwards, that varieties become races and, with time, come to constitute species, but it is not at all clear how far he thought this process continued or at what point he regarded natural law as ceasing and supernatural direction as intervening, for he says:

Will one dare to carry the spirit of system to the point of saying that it is nature, and she alone, which creates this astonishing diversity of means, of ruses, of skill, of precautions, of patience, of which the industry of animals offers us so many examples! What we observe in this respect in the class of insects alone, is it not a thousand times more than is necessary to compel us to perceive that the limits of the power of nature by no means permit her herself to produce so many marvels, and to force the most obstinate philosophy to recognize that here the will of the supreme author of all things has been necessary, and has alone sufficed to cause the existence of so many admirable things.[1]

There runs all through Lamarck's writings a teleological vein, which is, of course, not strictly scientific and which, on that account, is antagonistic to the general trend of Darwinism. Darwin several times expressed himself quite decidedly on this subject. For instance, in a letter to Asa Gray, written in November, 1860, he says:

I cannot think that the world, as we see it, is the result of chance; and yet I cannot look at each separate thing as the result of design. To take a crucial example, you lead me to infer that you believe "that variation has been led along certain beneficial lines." I cannot believe this; and I think you would have to believe that the tail of the Fantail was led to vary in the number and direction of its feathers in order to gratify the caprice of a few men.[2]

In another letter to Gray he writes:

I have lately been corresponding with Lyell who, I think, adopts your idea of the stream of variation having been led or designed. I have asked him (and he says he will hereafter reflect and answer me) whether he believes that the shape of my nose was designed. If he does, I have nothing more to say.[3]

The idea that all development proceeds along predetermined lines because all variations in structure arise with relation to definite objective ends is, without doubt, a form of the Paleyian doctrine of design. Whatever

[1] "Philosophie Zoologique," Packard's translation, in "Lamarck the Founder of Evolution," pp. 269–270. 1901.
[2] "Life and Letters," Vol. II., p. 353. 1887.
[3] *Ibid.*, p. 378.

force there is in Paley's argument for direct creation illustrated by the assemblage of the parts of a watch so as to produce a timekeeper, is also to be found in the Lamarckian conception of animal organs so shaped and united as to meet inevitably and always an immediate purpose. It is, therefore, no wonder that Lamarck fell back on supernatural intervention and direction in the various steps of animal evolution. Darwin never denied the existence of a creator, but he was totally unable to grasp the conception of interference in the successive stages of evolution, and the idea that nature's operations were in any sense foreordained to the production of organs *de novo* as and when needed to meet the emergencies of life was absolutely foreign to his whole habit of thought. The Lamarckian notion is that nature's laboratory turns out parts of animals (like the wheels of the Paleyian watch) simply and solely to meet demands (to fill orders, as it were) and is idle when the market is dull; the Darwinian conception, on the other hand, is that the productive energy of the universe is never still but is manufacturing models of infinite variety ready for any requirement that may arise, so that the species finally established in the world are results of choices made from the endless stock of diverse forms always available. Darwin frankly admitted that nature's policy, as he conceived it, was frightfully wasteful, since it called for the constant destruction of forms not needed and a continual production of others not likely to be wanted; but, notwithstanding a prevalent and pious desire to believe that nature's methods are more in accordance with the dictates of human wisdom and prudence, Darwin convinced the world that extravagance in the expenditure of living forms is a matter of undeniable proof. In fact, it became one of the chief aims of his philosophy to demolish what he regarded as a baseless and outgrown dogma, that everything in the world has a recognizably useful purpose. Lamarck's second law, embodying as it does at least a suggestion of this dogma, was repugnant to Darwin, and his lack of sympathy with it was the main reason why he contemptuously repudiated any indebtedness to Lamarck's writings. I am aware that Kölliker and others charged Darwin himself with being a teleologist, but I think that Huxley ably and effectually disposed of that accusation and that he was right in saying that, in natural history, teleology received its death-blow at Darwin's hands. Darwin declared, on his own behalf, that if every detail of structure could be shown to have been produced for the good of its possessor, or that structures had been created for beauty in the eyes of man, or for mere variety, it would be absolutely fatal to his theory. On this general subject Professor Huxley has made the acute remark:

According to Teleology, each organism is like a rifle bullet fired straight at a mark; according to Darwin, organisms are like grape shot of which one hits some-

thing and the rest fall wide. . . . . For the teleologist an organism exists because it was made for the conditions in which it is found; for the Darwinian an organism exists because, out of many of its kind, it is the only one which has been able to persist in the conditions in which it is found.[1]

Before Darwin's time biological problems were very generally complicated with *a priori* considerations and colored by mystical assumptions. Fanciful laws were frequently read into natural phenomena and the operations of the living world were often regarded not as they actually are but as it was imagined they ought to be. I do not mean to say there were not many conscientious and pains-taking followers of the inductive method, but, recalling the fierce conflict in which Darwin and his few faithful adherents were plunged immediately upon the appearance of "The Origin," and considering that the controversy raged largely around the question of the piety or the impiety of his views, I am convinced that the contest was mainly a phase of the oft-recurring clash between idealism and realism. Darwin brought biological science to the test of observation and experiment as it had never been brought before, and it is for this reason that we date from the year 1859 the last great renaissance, and that we recognize that in the past fifty years every department of learning in which research is involved has received a new impetus and a new breath of life. The underlying motive in all recent scientific investigation is the discovery of analogies, homologies and correlations which are the foundation stones of the theory of evolution, and it is Darwin, more than any other man who has ever lived, who has drawn the plans and written the specifications by which the great super-structure is being erected. If the artist who fashions the model in clay is the creator of the statue upon which the apprentice may work, if the architect who sketches the elevation and outlines the structural features of a palace is its originator, though ordinary laborers may lay the constituent blocks in place, Darwin, who first correctly described the fundamental principles underlying the development of the living world, and so pictured them as to make them realities to the minds of men, is entitled to the distinction and honor belongi g to the founder of the Evolution Theory of to-day, to the strengthening of which thousands of working naturalists are making their individual contributions.

His claim has been submitted to and passed upon by the only qualified jury,— the great body of men of science of the whole world, and the verdict has been rendered with substantial unanimity. In this year of centenary and semi-centenary celebrations, in particular, the general conclusion has been distinctly voiced. Learned bodies in all civilized lands have commemorated the hundredth year since Darwin's birth and the fiftieth year since the

[1] Essay on "Criticisms on The Origin of Species," in "Darwiniana," p 84. 1902.

publication of his imperishable book, and have placed on record their estimates of the transcendent importance of his work and the permanence and universality of his influence. Essay after essay has been printed, and volume after volume has been published, all to set forth the fact that to no one else, as much as to Charles Darwin, is the intellectual world indebted for a revivifying and newly impelling thought. Among all the gatherings of the year the most representative and the most important was the congress which assembled in Cambridge, England, last June. At that convocation nearly every nation which values culture and every department of higher learning were represented. No such assemblage was ever before convened to pay tribute to the memory of a scientific worker, and I think I am safe in asserting that none such could be brought together to honor the name of any of the earlier advocates of evolution. There was a mere handful of foreign scientists at the dedication of the Lamarck statue in Paris, although delegates were flocking from every direction to Cambridge, and many of them probably could have stopped over at Paris if they had felt disposed to divide honors between Lamarck and Darwin. I think Dr. L. O. Howard, of Washington, was the only American present in a professional capacity and that I was the only one among *hoi polloi*, whereas at Cambridge thirty-two American institutions were represented by more than a score of delegates.

To the Darwin celebration, two hundred and forty-two institutions, of twenty-nine different countries, sent two hundred and thirty-three delegates who, with one hundred and eighty-seven other invited guests, constituted an impressive convention of four hundred and twenty persons. This was no perfunctory meeting,— it was a gathering with the serious purpose of pronouncing a final judgment. It was animated by a spirit of triumph. Its meaning was that Science as a whole had come into its own and that Charles Darwin was the leader who had brought it into the promised land. In public speech and private conversation there was one dominant note of exultation, and this was sounded alike by biologist and theologian, by physicist and metaphysician, by experimentalist and philosopher,— all hailing the day of freer thought and wider mental out-reach due preëminently to the advent of the idea of evolution set once for all upon a sound logical foundation by Charles Darwin.

Among other important mementos of that great occasion is a volume of twenty-nine essays specially prepared at the request of the Cambridge Philosophical Society, and published by the University Press, under the title "Darwin and Modern Science." These essays are intended to set forth, in a composite picture, the various departments of learning to the advancement of which Darwin's researches and writings have contributed, but their significance is not so much in the completeness or accuracy with which they

rehearse Darwin's achievements as in the sincerity and cordiality with which they acknowledge the indebtedness of all branches of knowledge to his shaping and guiding influence. They contain repeated references to him as the Newton of the biological sciences and constantly acclaim him as the greatest of generalizers. They also attempt, in some measure, to explain the causes of his extraordinary success, and perhaps I can not do better than to bring this address to a close by quoting from the first essay in the book a few sentences which seem to me to epitomize the case more clearly than I can do in my own words. "How is it that Darwin succeeded where others had failed?" asks Professor J. Arthur Thomson. "Because," he replies, "in the first place, he had clear visions — 'pensées de la jeunesse, exécutées par l'âge mûr'— which a university curriculum had not made impossible, which the Beagle voyage made vivid, which an unrivalled British doggedness made real,— visions of the web of life, of the fountain of change within the organism, of the struggle for existence and its winnowing and of the spreading genealogical tree. Because, in the second place, he put so much grit into the verification of his visions, putting them to the proof in an argument which is of its kind — direct demonstration being out of the question — quite unequalled. Because, in the third place, he broke down the opposition which the most scientific had felt to the seductive modal formula of evolution by bringing forward a more plausible theory of the process than had been previously suggested.— Nor can one forget, since questions of this magnitude are human and not merely academic, that he wrote so that all men could understand.

"To sum up: the idea of organic evolution, older than Aristotle, slowly developed from the stage of suggestion to the stage of verification, and the first convincing verification was Darwin's; from being an *a priori* anticipation it has become an interpretation of nature, and Darwin is still the chief interpreter; from being a modal interpretation it has advanced to the rank of a causal theory, the most convincing part of which men will never cease to call Darwinism."

[ANNALS N. Y. ACAD. SCI., Vol. XIX, No. 11, pp. 247-282, Pll. XXIII, XXIV.
21 April, 1910]

AREAL AND STRUCTURAL GEOLOGY OF SOUTHERN MANHATTAN ISLAND[1]

BY CHARLES P. BERKEY

(Read in abstract before the Academy 7 December, 1908.)

CONTENTS

[1] Published by permission of the New York City Board of Water Supply, under whose direction the original study was made. A report covering nearly all of the data now included in this paper and all of the essentials of the new interpretation of areal distribution and geologic structure was submitted to the Chief Engineer, J. Waldo Smith, Oct. 30, 1908. At that time there were no borings in the Lower East Side section, except an occasional one on the water front, and the interpretation was based on a very small amount of evidence. Since that time, the Board of Water Supply has explored the district, especially along Delancey, Hester and Clinton Streets, to a sufficient extent to establish the main features of the revised structure.

General Features of Local Geology

A considerable portion of Manhattan Island is so heavily covered with drift that the underlying rock formations, as to type and structures, cannot be seen. This cover is especially prominent in the southern portion of the island. The northern portion, on the contrary, has many ridges of outcrops so distributed that the structural relations are quite definitely settled. Because of the southerly strike of these formations, it is quite certain that they continue beneath the drift to the southern extremity of the island at a depth of from zero to 150 feet below the surface. But the available maps representing the areal distribution of these formations are somewhat in error for certain portions of the covered area.

The observations upon which the writer's conclusions are based are chiefly drill-borings, tunnels and deep foundations that together constitute a considerable mass of information, some of which was not formerly accessible. These data are tabulated and conveniently arranged for reference and comparison in the latter part of this paper in such a way as is thought to be useful for future exploration and investigation.

Formations

A preliminary statement, however, may be necessary as to the identity and characteristics of the chief formations to be considered. Of these there are only three of large importance: the Fordham Gneisses at the bottom; the Inwood Limestone overlying, and the Manhattan Schist, the topmost

member. Each of these exhibits a considerable variety of composition, texture and structural quality, and two especially — the gneisses and the schist — are, in some cases, so nearly alike in appearance that they are distinguished with great difficulty. This is particularly true in cases where small outcrops must be relied upon, or where there are no outcrops, and the information is confined to fragments recovered from borings. The difficulty is still greater where the chop drill has been used and the rock broken to very small bits, or grains. In some of these cases, it is the writer's opinion that it is impossible to identify every specimen. A thorough acquaintance, however, with the possible range of petrographic characters will enable one to identify any reasonably typical specimen, and where several from the same general locality are available, there is never any serious doubt of the identification. In the older records of engineers and some of the city departments, very general terms are used for bed-rock, the terms granite, schist and gneiss being used rather promiscuously for the crystalline basement without distinguishing between the different large formations. In a study of this material for the unravelling of the structural geology, however, it is essential to identify the specific formation to which each specimen belongs. The following descriptions may serve as a guide for such determination.

Fordham Gneiss

The most characteristic Fordham Gneiss is a close-textured, black and white banded quartz-feldspar-hornblende-mica rock of a general composition similar to a very quartzose granite. The bands are seldom more than an inch or two in width, rather persistent, frequently crumpled or folded and usually hard and durable. There is a general foliated structure which, in some places, is not very noticeable and in others is very strong. This typical Fordham is easily identified, but large areas and numerous belts or streaks of this formation exhibit no banding at all. On the contrary, they are comparatively massive and have all of the characters of a gneissoid granite, diorite or granodiorite. Less commonly the rock exhibits a strongly quartzose character, becoming a quartzite schist. Associated with this type may be found a more strictly mica or hornblende schist of uniform structure, and still more rarely very impure limestones interbedded with the gneisses are found. The banded type is very prominently exposed in the northern part of Manhattan Island along Seventh Avenue and is still more strongly developed on the east side of the Harlem River in the Bronx. The massive types are much more common in the exposures in the East River, Long Island City, Brooklyn and in certain drill borings of southern

Manhattan on the lower east side. The most massive type is undoubtedly an intrusive. On account of its typical development in Long Island City the writer suggests the name Ravenswood granodiorite for the type.

Inwood Limestone

The Inwood is generally a very coarse-grained, crystalline limestone. The chief variation is in the presence of mica and chlorite flakes, which, at some points, become so abundant as to form calcareous mica or chlorite schist rather than limestone. This is especially true wherever shearing has affected the formation, as along certain fault zones, and where underground circulation has dissolved some of the lime, leaving the less soluble constituents. In some cases of this kind, the resulting residuary material bears no resemblance to the ordinary, typical Inwood. The genetic relations, however, are seldom obscure even in the worst or most modified cases.

Manhattan Schist

The Manhattan is the most variable formation. Typically, it is a coarse quartz mica schist. The mica flakes are large and constitute the larger proportion of the rock in most cases. Quartz, however, is abundant; feldspar less abundant than in the gneisses. The rock is usually not banded but irregularly streaked and complexly crumpled with numerous lens-like developments of segregated quartz and other secondary minerals. In its most characteristic facies, biotite and a white, silvery or pearly mica is found. This pearly mica is probably the most characteristic constituent of the Manhattan formation. Its presence in any considerable amount makes identification reasonably certain. In the Manhattan, however, are numerous varieties of very different character, some of which are essentially identical with those occurring in the Fordham Gneiss. They are chiefly intrusive types and vein-like developments that occur as streaks or bands or masses of hornblende schist, granite, pegmatite and similar rocks. It is evident that whenever these types are the only representatives to be found, the identification is wholly uncertain. An additional variety is the serpentine and amphibolite or so called "anthophyllite," but this has a limited distribution and nowhere, so far as the writer is aware, leads to any confusion of identification.

Many minor variations occur, and the change takes place rapidly, showing a great range in a single outcrop. In some places much epidote is developed, so that the rock is a typical epidote schist. It would be possible, on this account, to sub-divide these three formations into a considerable

number of rock varieties, but in this and for the present purpose there is no advantage since structurally the three great formations behave as units.

Glacial Drift

Covering the whole series is the loose mantle, known as the Glacial Drift, which exhibits a complex and variable structure. All varieties from characteristic till to perfectly assorted sands and clays are to be found. The whole cover, so far as this study is concerned, serves chiefly as an obscuring mantle. Not only is the rock underneath hidden, but the structural relations are to an equal degree obscured.

Structural Relations

The three large formations have each been so much modified by metamorphism and have suffered so much disturbance in the process, standing in such marked contrast with any other formations of adjacent areas, that they are commonly thought of as a single series or simple succession of formations; but of this there may be some question. There is, however, no doubt that the Fordham Gneiss is the oldest formation known in southern New York, that it is in part a metamorphosed sediment and in part made up of igneous intrusions cutting the older sediments in a most complex way and occasionally forming much more than half of the rock. There are typical quartzite beds and recrystallized limestone layers here and there in the banded Fordham. These are sufficiently clear evidence of sedimentary origin for those portions, but it is equally clear that other belts or areas are igneous, and between the two there is such variety and such extensive penetration, segregation, inclusion and recrystallization that it is wholly impossible to draw the lines of origin very close.

There is sufficient evidence in adjacent districts to establish the fact that there must be a considerable time break between this lowest member (the Fordham Gneiss) and the next overlying Inwood Limestone. Whether it is an unconformity of large value or more of the nature of an overlap is not determinable in this region, because of the closely crumpled and infolded relation that they now exhibit. The Inwood Limestone and the Manhattan Schist are mutually conformable, with some development of inter-bedding in the transition zone. Only the drift or, rarely, residuary matter from decay lies above these formations.

Nothing older or lower than the Fordham Gneiss is known on Manhattan Island, and therefore its depth is indefinite. The Inwood Limestone may be regarded as between 700 and 900 feet thick at its best development, and the Manhattan Schist above is of great but unknown thickness.

Folds and Faults

These formations are everywhere folded into a succession of anticlines and synclines whose axes trend northeastward. They have also suffered extensive erosion, so that the crests of all the anticlines are truncated, with the result that in the present areal distribution these formations lie side by side in long relatively narrow belts. The axes of these folds are by no means straight for any great distance, neither are they horizontal. In general, all of the folds pitch southward at gentle angles and take occasional bends. Therefore in passing southward, whether on an anticline or in a syncline, higher and higher formations or beds are met with. So it happens that on Manhattan Island the Manhattan Schist, the highest member, increases in areal distribution until it covers most of the width of the island. But everywhere, unless there has been some additional displacement, there is a belt of limestone between the schist and gneiss. Most of the folds are unsymmetrical, and sometimes they are overturned.

Both longitudinal and cross-faults occur, but there is no doubt that the former are of most prominence. In the East River at Blackwell's Island almost the whole thickness of Inwood Limestone, which should be found between the schist and gneiss, is lacking. The residuary matter and condition of the bed rock, as shown in the Seventieth Street tunnel of the East River Gas Company, indicates crushing and much decay, such as should be expected in a fault zone, and there is every reason to regard it as a fault. Doubtless there are others of similar displacement, but their relations are such that the effect is too obscure to be readily seen. Numerous weak zones of a similar sort run across the formations in a general northwest-southeast direction. It is probable that most of them represent actual cross faults. The throw is probably not great in any case, and the off-set is usually insignificant. These zones, however, control the distribution of cross valleys, some of which, like the Manhattanville Valley, are among the most striking features of the island.

Areal Distribution

All the formations lie beneath the drift in more or less regular belts,—narrow if closely folded, or comparatively wide if more gently folded,—and with a northeasterly strike. The Inwood Limestone lies normally between a schist belt and one of gneiss and is usually narrow. It always holds this position unless cut out by faulting.

Irregularities in distribution are common. They are chiefly of the nature of bends in the course or strike of the formation, a widening of the belt locally, a disappearance or an emergence due to cross-folding or local

changes in pitch, — some due to faulting, and others due to igneous intrusion. The abundance of these irregularities makes it doubly difficult to trace a formation or contact beneath the drift any great distance beyond actual outcrops. For this reason, in southern Manhattan, drill holes, foundation excavations and tunnels have great value in determining a more reliable distribution. It was a study of all known sources of such information that first suggested the changes in areal and structural geology of Manhattan that are here given.

Areal and Structural Corrections[1]

Below Central Park there is now little evidence to be gathered at the surface as to areal or structural geology, but as far south as Thirtieth Street the bed-rock geology is pretty well known from earlier reports and from recent improvements that have exposed the underlying rock. All of this portion is mapped as Manhattan Schist, except one small area of serpentine at Fifty-ninth Street between Tenth and Eleventh Avenues. There is no reason to modify this usage in that portion of the island. A careful study of a great number of rock specimens from the Pennsylvania Railroad tunnel across Manhattan at Thirty-second Street proves beyond question that the bed rock is Manhattan Schist, including almost all known variations and accompaniments, for the whole width of the island along that line.

Farther south the points that have furnished exact information about bed-rock are less numerous, and below Fourteenth Street they are confined to deep borings or an occasional deep excavation for foundation. Even these sources of information are lacking over large areas. The greater number of borings available are along the water front. Their character and distribution are such as to indicate that the west side and central portion of the island are underlain by Manhattan Schist. (See accompanying map on which these data are plotted.)

This is true entirely to the East River at Twenty-seventh Street and as far eastward as Tompkins Square at Tenth Street and almost to the Manhattan tower of Brooklyn Bridge in that vicinity.

To the eastward of these limits, that is, to the eastward of the line projected from Blackwell's Island to the Manhattan tower of Brooklyn Bridge (Bridge No. 1), there is evidence of a more complicated geology. The borings of the East River front are decidedly variable. They are certainly not all Manhattan Schist. Those most unlike the Manhattan are at the same time most like some varieties belonging to the Fordham Gneiss, and it

[1] Based upon the data tabulated on pages 260–281.

is certain that this formation also occurs. In that case the Inwood should also be found between the other two. The lack of data at first, except along the water front, made it impossible to draw more than very general lines. Drawn in this way, of course, the lines are too regular and straight, but it is certain that they indicate more nearly the actual existing areal distribution of formations than any of the maps now in use.

A southward extension of the Blackwell's Island anticlinal belt of Fordham Gneiss reaches across the East River in a long narrow strip toward the Manhattan tower of Brooklyn Bridge. How much of this anticlinal fold would actually expose the Fordham, if the drift were scraped off, it is impossible to say, but it is certain that this formation exists there. Inwood Limestone must be accounted for, unless faulted out, on the west side of this belt, and then the Manhattan Schist occupies the area westward to the Hudson River.

On the east side of this Fordham anticline, a parallel belt of Manhattan Schist and associated Inwood Limestone is to be expected, as indicated on the map, and this is succeeded by Fordham Gneiss which occupies the eastern border of the island in the district known as the "Lower East Side."

Explorations made some years ago along the line of the gas tunnel [1] across the East River at Seventieth Street indicate comparatively narrow belts of limestone there in both the east and west channels. Their limited width, together with the accompanying strongly developed disintegration zones, indicates rather extensive squeezing out and faulting of this formation along planes parallel to the strike. Such movements, of course, are capable of entirely cutting out the intermediate limestone from between the schist and gneiss. How much of this condition exists in the continuation of these zones southward through Manhattan, it is impossible at present to say.

The intermediate belt is indicated on the map as a continuous schist-limestone area, and at one point, at least, the limestone is known to occur, namely, on the southeastern margin of the Manhattan pier of the Manhattan Bridge (Bridge No. 3) at the Foot of Pike Street, where it was penetrated by a drill in exploring for the bridge site. It is not probable, however, that there are continuous limestone belts of any considerable areal importance, else the East River would have been able to follow them and could thereby have taken a more direct course than it now does. At any rate, there is a probability of finding three belts of limestone, unless they are cut out by faulting.

On the Brooklyn side, no formation of the series except the Fordham and its associated igneous masses, such as the Ravenswood granodiorite,

---

[1] J. F. KEMP: The Geological Section of the East River at Seventieth Street, New York. Trans. N. Y. Acad. Sci., Vol. xiv, p. 273. 1895.

have been identified with certainty within the area reached by this study. Limestone is reported near Newtown Creek a little beyond the eastern margin of the map.[1] There has been no opportunity to verify this record.

The above suggestions on the geology of the region south of Fifty-ninth Street are embodied in the accompanying map. Each boring whose record and material could be verified and personally inspected is plotted and marked to indicate the rock. No dependence was placed upon any records, if the material could not be seen.

There is no reasonable doubt that folds, faults, crush zones and decayed belts occur as frequently in this southern portion of Manhattan as in other better known adjacent areas, but they cannot be so definitely traced or mapped. It has been found in some places that surface drainage lines mark roughly the trace of certain structural weaknesses, even where heavily drift covered, but this is not always true. There is nowhere any evidence of very important cross structures such, for example, as the Manhattanville valley or Spuyten Duyvil Creek of northern Manhattan.

The problems of this area, therefore, are concerned chiefly with the longitudinal structures produced by folding and faulting and subsequent disintegration and decay along the crush zones that sometimes accompany them.

A generalized geologic cross-section showing structural relations across this area in the vicinity of Williamsburg Bridge based on an interpretation of areal geology, as outlined above, is given in Plate XXIII.

East River Channel

The East River is still more abnormal with this rearrangement of areal and structural geology. Instead of following the belts of limestone as was formerly supposed, it seems to have cut across all of the formations twice in the great bend below Twenty-seventh Street. There is no structural explanation better than the suggestion that it is controlled by a combination of intersecting cross fractures and weak zones across the gneiss of enough prominence to overcome the usual tendency to follow the strike of the limestone. It is worth noting that the Harlem River has a very similar course due rather certainly to cross-faulting, and that Hell Gate, Little Hell Gate and Bronx Kills are all of similar structural relation. It is believed that the portion of the East River between the Williamsburg and Manhattan bridges flows on the gneiss and that this part of the channel has less complexity of structure and less uncertainty of condition than any other of the waterways about the island.

[1] VEATCH, as quoted by W. H. HOBBS: U. S. Geol. Surv. Bull. No. 270, p 86

It is not overlooked of course that the irregular covering of drift probably is the most important factor in modifying the courses of many minor streams. This is true for the East River, also, in its lower portion. It is a displaced stream in part,— shoved southward out of its original course, which doubtless was a more direct one parallel to the formations. In the submergence following the withdrawal of the Glacial ice a channel was established wholly on the drift and more than usually free from structural control. This is the present East River course from Blackwell's Island southward.

Explorations now in Progress and Their Bearing

The conclusions reached in this paper were the outgrowth of a careful and detailed study of local conditions for the New York City Board of Additional Water Supply. The immediate importance of such modification of interpretation of Manhattan geology lies in the fact that it is considered advisable to bring the new Catskill water supply down through the city in a tunnel deep enough in bed rock to insure its permanence and safety. The changes and conditions of bed rock are therefore of very practical importance, and explorations in accord with the interpretations contained in the preceding chapter have now been in progress for several months. Points that were considered most critical were selected first with the idea of at once proving or disproving the new views of geologic structure.

It is too early to draw sweeping conclusions or to give details, but enough has been established by the half-dozen holes already drilled to prove beyond question that in general the new interpretation of areal and structural distribution and relations is correct. Inwood Limestone was found in the first hole located to explore for it. The Fordnam Gneisses were also found as indicated. No doubt much more detail and accuracy of boundary lines can be given at the conclusion of this new work. (See borings tabulated as Nos. 300–314).

Configuration of the Rock Floor

A series of observations on borings in progress and occasional well preserved boring materials from earlier work lead one to the conclusion that the rock floor of New York is very imperfectly represented in any attempt yet made. The reasons for this imperfection are many, but chiefly they are the misleading information of drill records and the almost total lack of discrimination between different types of loose material by drill men.

In most cases it has been assumed by drillers that everything above the

point where solid core could be secured is drift cover. Yet a little critical examination of materials will show that in some places the drill penetrates a thick layer of residuary (decayed) matter belonging to the formation below the drift. Occasionally such disintegration is so complete that core cannot be saved for a depth of 50 to 100 feet after leaving all traces of the drift cover. Recent explorations and those now in progress confirm this view. In addition, it is clear that such decay is more pronounced on the limestone belts and along known crush-zones, and these are sometimes very narrow.

To increase still more the uncertainty and imperfection of many records, it is not at all unusual to strike large bowlders in drilling which give every apparent behavior of rock ledge. Where the only thing sought is depth to bed rock, therefore, many such finds are reported as rock floor. Some of these show, by the material recovered from them, that the rock is not of local type, but this is usually overlooked because of lack of critical knowledge of the variations allowable in the local formations.

It is the writer's opinion, therefore, that it is impossible to construct a map showing the topography of the rock floor of southern Manhattan. The bulletin by Professor William Herbert Hobbs [1] is a good attempt at such a study, but it is certain that the contour lines of southern Manhattan are very different south of Twenty-third Street. The map is of great service, however, for the larger number of records of depth to rock given than heretofore and for the handy form in which they are available for combination with accumulating data of more detailed and more accurate character.

Tabulated Records of Borings in Southern Manhattan Island

The information combined in the tables which follow has been accumulated in a systematic inspection of every drill core that could be seen from southern Manhattan and the other side of East River. Most of the material is the property of the various New York City departments, the Public Service Commission and large transportation companies as noted below. Scattering groups of cores represent private operations for deep wells, or plunger elevators, or tests of foundations or railroad tunnels. Many of these have been tabulated as to location and depth to rock by Hobbs,[2] but in his discussion the type of rock in each case was accepted as originally identified at the time the borings were made. Some of these are old, made

[1] U. S. Geological Survey, Bull. 270. Plate I. 1905.
[2] *Op. cit.*

before the present ideas of the differentiation of formations on Manhattan or their structure were known, and some were in the care of engineers and others who made no special claim to a knowledge of rock classification. Besides, the purposes for which they were usually taken seldom made it necessary to know anything more than that bed-rock had been reached and that it was substantial enough for foundations. The depth to rock was almost the only information needed in most cases. It is, therefore, somewhat surprising, all things considered, that these materials have been so intelligently noted and so carefully preserved. Some of them are from twenty to thirty years old, but the greater number have been gathered within the past fifteen years. In many cases no one has made examination of them since their original individual purpose was fulfilled.

No other enterprise has found it so necessary to follow up all these sources of bed-rock information. Therefore this is the first time any one has examined all of these data in an attempt to classify them and use the information in interpreting the rock structure and formational geology of the areas covered hopelessly beneath the heavy drift cover of the southern part of the city. The task has required more work than is likely to be warranted soon again. Believing also that the information may be occasionally serviceable in tabulated form, as well as in interpretations reduced to geologic maps, the following sets of abbreviated notes are offered for preservation in the records of the Academy.

I am well aware that these notes leave much to be desired. It is often absolutely impossible to classify a bit of rock from a drill core or identify it with any particular local formation. This is because of the similarity of certain varieties of two of these formations,— the Manhattan Schist and the Fordham Gneiss. Occasionally in a boring only a few small chips represent all that is recovered or saved. An extensive core or a group of specimens almost always makes it possible to determine the identity with satisfaction. I have taken some care to indicate whether the classification given is reasonably certain, or simply a preference for one of the possible formations, or whether it is entirely indeterminate. I am sure no one will more fully appreciate the difficulty of making a rigid classification of such cores than the men who know these formations best.

The tabulation includes location, depth to rock, depth uniformly corrected to U. S. Coast and Geodetic Survey datum, which is mean sea level at Sandy Hook, penetration of the rock, present classification as to relationship to local formations and variety or quality of special features. It is not generally possible to give data of value as to percentage of core recovery, for the reason that it is not possible to know whether or not the original core was all saved.

In this tabulation only the three formations of recognized large importance are taken into account, as follows:

(1) The Fordham Gneiss, which is the lowest and oldest and most complex, including the Ravenswood granodiorite as a special variety;
(2) The Inwood Limestone, or dolomite, which is the next younger and lies above the Fordham;
(3) The Manhattan Schist, which is the uppermost formation.

All types are referable to one or another of these three formations as varieties or facies or associated units of minor structural significance.

Public Service Commission

Borings made in Investigations for Subways

There are six lines of borings across East River, as follows:

a)	South Ferry,	N. Y.,	to Joralemon	St.,	Brooklyn.
b)	Old Slip,	"	" Montague	"	"
c)	Maiden Lane,	"	" Pineapple	"	"
d)	Beekman St.,	"	" Cranberry	"	"
e)	Fourteenth St.,	"	" No. Seventh	"	"
f)	Thirty-fourth St.,	"	" Long Island City, R. R. Station.		

These materials are carefully labeled and housed in the rooms of the Commission. Samples of rock were taken by a diamond drill, and all are of small diameter. They have been examined especially for evidence as to the quality and variety of rock represented, and the classification and relationship to the standard local formations is indicated wherever possible.

The datum to which all borings have been uniformly reduced is mean high water of the Rapid Transit Commission, which is 2.72 feet above mean sea level at Sandy Hook,— the datum of the U. S. Coast and Geodetic Survey, as well as that of the N. Y. City Board of Water Supply.

a) South Ferry (New York) to Joralemon St. (Brooklyn), across East River.

Serial No.	Original Mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
1	1	3,210′ E. of end of pier 4, E. R.	....	....	....	....	No rock at −63.31′.
2	2	1,558′ E. ditto	....	....	....	....	No rock at −97.51′.
3	3	1,988′ E. ditto	....	....	....	....	No rock at −86.71′.
4	4	2,145′ E. ditto	−56.7′	−53.98′	21.3′	Manh.	Hornblende-biotite-quartz schist, not typical.
5	5	1,152′ E. ditto	−69.0′	−66.28′	20 1′	"	Mica schist, regular type.
6	6	510′ E. ditto	−54.8′	−52.08′	27.2′	"	Hornblende-biotite-epidote-quartz schist, not typical.
7	7	857′ E. ditto	−62.24′	−59.52′	14.96′	"	Core not seen.
8	8	Pier No. 4 (end)	−30.0′	−27.28′	41.0′	"	Garnetiferous and pegmatitic Hornblende-biotite schist.
9	9	Pier No. 3 (near end)	−27.9′	−25.18′	31.8′	"	Mica schist, curly, common type.
10	10	South St. and Whitehall	−22.2′	−19.48′	20.5′	"	Common type with pearly mica. Lies rather flat.

b) Old Slip (New York) to Montague St. (Brooklyn), across East River.

11	3451	Near Old Slip	−36.0′	−33 28′	21 0′	Manh	Coarse, curly mica schist. Core 14 ft.
12	3452	800′ E. of pier headline	−49.0′	−46.28′	11.0′	?	Hornblende schist core 9½ ft. Probably Manhattan.
13	3453	1040′ E. ditto	−53.0′	−50.28′	11.0′	Ford.	Granitic gneiss 50–60° dip, core 9 ft.
14	3454	1425′ E. ditto	−71.0′	−68 28′	8.0′	?	Pegmatitic granitic gneiss, probably Fordham.
15	3455	Pier (Brooklyn)	....	....	....	....	No rock at −71.51′.

c) Maiden Lane (New York) to Pineapple Street (Brooklyn), across East River.

16	3456	400′ E. of pier headline	−67.0′	−64.28′	11.0′	Ford.	Granitic gneiss dip vertical, uniform core 9 ft.

d) Beekman St. (New York) to Cranberry St. (Brooklyn), across East River.

17	3457	925′ E. of pier headline	−95.0′	−92.28′	3.0′	?	Mica schist probably bowlders.
18	3458	100′+ E. of pier headline	....	....	....	....	Rock or bowlders at −91.51′.

e) Fourteenth St. (New York) to North 7th St. (Brooklyn), across East River.

Serial No.	Original Mark	Location	Depth to rock M. H. W	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
19	3460	50′ E. of pier headline	−53.0′	−49.28′	11.0′	Drift.	No ledge. Trap bowlder, etc.
20	3461	450′ E. ditto	−72.0′	−69 28′	15.0′	Ford.	Granitic gneiss coarser and more garnetiferous than usual.
21	3462	800′ E. ditto	−62 0′	−59 28′	11.0′	" ?	Garnetiferous granitic gneiss, core 10 ft. (same).
22	3463	1150′ E. ditto	−65.0′	−62.28′	12.0′	" ?	Granitic gneiss, core 11′ (same).
23	3464	1600′+E. ditto	−57 0′	−54.28′	10.0′	Manh.	Mica schist and pegmatite, 9′.
24	3465	2100′+E. ditto	−86 0′	−83 28′	8.0′	"	Garnetiferous 7 ft.
25	3466	2250′ E. ditto					No rock at −120.51′.

f) 34th St. (New York) to L. I. City R. R Station, across East River.

Serial No.	Original Mark	Location	Depth to rock M. H. W	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
26	3467	525′ E. of 35th St. pier end	−72.0′	−69 28′	11 0′	Manh.	Mica schist, finer than usual, dip 50°.
27	3468	575′+E ditto	−59.0′	−56 28′	8.0′	Ford.	Banded granitic gneiss, dip 65°.
28	3469	800′ E. ditto	−64 0′	−61.28′	13 0′	"	Micaceous granitic gneiss dip 45–50°.
29	3470	1000′ E. ditto	−54 0′	−51.28′	9 0′	Manh.	Mica schist, dip 45°.
30	3471	1240′ E. ditto	−74 0′	−71 28′	10.0′	"	Mica schist garnetiferous and fine grain, flat.
31	3472	L. I. City pier headline	−52 0′	−49.28′	11.0′	"	Mica schist, finer grain than usual.
32	3473	Front St. L. I. City	−38.0′	−35.23′	2 0′	Ford ?	Rather coarse mottled granitic gneiss.

New York and Long Island Railroad Company

Belmont Tunnel

This company has completed a tunnel across the East River from Forty-second Street to Long Island City, known as the "Belmont Tunnel." Numerous wash borings and several diamond drill borings were made. The figures for depth and rock penetration are taken from the drawings of the company. The datum is mean high water and is the same as the M. H. W. datum of the Rapid Transit Commission, 2.72 feet above mean sea level at Sandy Hook. The depths to rock have been corrected, there-

fore, to correspond to this datum, which is also the datum of the Board of Water Supply. All three of the rock formations of this district are penetrated by these holes. One is in Manhattan Schist, one is in typical Inwood Limestone and three are in the oldest formation, the Fordham Gneiss. Three others, supposed to have struck rock, seem to me not to have reached it, and two others penetrate decayed and disintegrated rock of so badly altered character that it cannot be accurately identified.

Serial No.	Original Mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
33	1	Pier headline	-68.0′	-65.28′	32.7′	Manh.	**Mica schist typical.**
34	2	60′ E. ditto	....	....	...	Drift	**No bed-rock at -99.0′.**
35	24	330′ E. ditto	-93.0′	-90.28′	7.0′	Inw'd.	**Coarse dolomitic crystalline limestone.**
(Pieces were found at about 75–77′ first and still further down. The material is disintegrated micaceous variety of Inwood Limestone.)							
36	3	585′ E. ditto	....	-108.0′	...	?	Arkose sand. May be disintegrated Fordham -101, -108. No solid bed-rock at -108′.
37	4	900′ E. ditto	-37.4′	-34.68′	52.2′	Ford.	Granitic gneiss banded and very micaceous.
38	4A	1150′ E ditto	-60.2′	-57.48′	29.8′	"	Granitic gneiss more micaceous than usual.
39	5	1380′ E ditto	....	-107.28′?	....	Drift	Probably no rock at -107.28′.
40	6	1775′ E. ditto		-87.58′		?	Micaceous green mud, probably decomposed micaceous limestone (Inwood). No solid ledge.
41	7	2190′ E. near pier headline	....	-87.68′?	....	Drift	Probably no ledge at -87.68′
42	8	L. I. R. R. Co.'s pier	-45.9′	-43.18′	24.1′	Ford.	Granodiorite of mottled garnetiferous type, massive and streaked.

Department of Bridges

The materials obtained by drill borings in investigations for sites of piers and anchorages for bridges across the East River have been examined. These materials are housed at different places as indicated below in each case. In general, the evidence of bridge borings is especially satisfactory and definite because of the fact that they are always in groups. This gives opportunity to compare several from a single area and to correct or cor-

roborate the judgment of their character and relationship. I have been assisted in every way by the engineers in charge in finding and handling these materials.

The East River bridges are known as

No. 1, or the "Brooklyn Bridge."
" 2, " " "Williamsburg Bridge" or the "New East River Bridge."
" 3, " " "Manhattan Bridge" (now being constructed).
" 4, " " "Blackwell's Island Bridge" or "Queensboro Bridge."
" 5, (A projected one on the northeast side and immediately adjacent to Brooklyn Bridge).

Bridge No. 1, "Brooklyn Bridge"

Datum is M. H. W., 1.93 ft. above mean sea level at Sandy Hook. No cores seen.

(See Bridge No. 5, which gives data for the same locality on both the Brooklyn and New York sides.)

Bridge No. 2, "Williamsburg Bridge" or "New East River Bridge"

Materials from drill borings at both piers are completely labeled and housed in the office in Brooklyn, 84 Broadway. They are one inch diamond drill cores and are lettered A, B, C, etc., on each side of the river. The datum is M. H. W. and is 2.67′ above mean sea level at Sandy Hook (U. S. datum).

a) *Brooklyn Tower foundation.*

Serial No.	Original mark	Location	Depth to rock M. H. W	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
43	A	N. pier E. side	-105 0′	-102.33′	7.04′	Ford.	Granitic gneiss rather flat, 6′ core.
44	B	Center line of bridge E. side	-80 4′	-77 73′	16 73′	"	Granitic gneiss, 9′ core, 15° dip.
45	C	N. pier W. side	-96 7′	-93 03′	16 0′	"	Black and white banded granitic gneiss, 3′ core
46	D	Center line of bridge W. side	-85 0′	-82 33′	20.24′	"	Quartzose gneiss, some hornblende type. 17′ core. 10°–25° many pieces
47	E	S. pier E. side	-80 0′	-77.33′	10 35′	"	Gray banded granitic gneiss, 6′ core, steep dip.
48	F	50′ S. of S. pier	-76.0′	-73.33′	14 0′	"	Striped gray granitic gneiss, 8′ core, 50° dip.

a) Brooklyn Tower foundation. (Continued.)

Serial No.	Original mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
49	G 2	S. pier S. W. corner	-89.4′	-86.73′	10.58′	Ford.	Hornblendic gneiss, some strongly banded.
50	H 2	S. pier S. E. corner	-81.0′	-78.33′	13.29′	"	Granitic gneiss, 8′ core, 50°–60° dip.
51	K	N. pier N. E. corner	-102.3′	-99.63′	7.8′	"	Gray granitic gneiss, 6′ core.
52	L	N. pier S. E. corner	-88.0′	-85.33′	13.0′	"	Gray granitic gneiss, 10′ core.
53	M	N. pier N. W. corner	-104.0′	-101.33′	11.0′	"	Hornblendic granitic gneiss, typical Fordham, 6′ core, 10°–30° dip.
54	N	N. pier S. W. corner	-86.0′	-83.33′	10.5′	"	Granitic gneiss, 10′ core.

b) New York anchorage.

Serial No.	Original mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
55	A	Near S. W. corner of anchorage	-65.2′	-62.53′	?	"	Banded hornblendic granitic gneiss and schist, uncommon, 14′ core, 45° dip.
56	B	Tompkins St. near S. E. corner	-64.4′	-61.73′	?	"	Banded granitic gneiss, micaceous, 9′ core, 30° dip.
57	C	W. side E. of center line	-70.8′	-68.13′	?	"	Streaked micaceous granite gneiss and pegmatite. 8′ core.
58	D	E. side, N. of center line	-69.5′	-67.83′	?	" ?	Fine grained, garnetiferous mica gneiss. Upper part unusual type. Lower part favors Fordham 7′ core, steep dip.
59	E	N. W. corner	-63.6′	-60.93′	?	" ?	Mica gneiss, coarser than usual, 8′ core.
60	F	N. E. corner	-63.1′	-60.43′	?	" ?	Mottled grayish granodiorite gneiss, with garnets, 12′ core.
61	G	N. E. corner 20′ W.	-60.2′	-57.53′	?	"	Streaked micaceous granitic gneiss.
62	H	S. E. corner	-95.1′	-92.43′	?	"	Grayish, garnetiferous, granitic gneiss. Mostly typical Fordham, 12′ core.
63	K	N. W. of center	-76.5′	-73.83′	?	"	Granitic gneiss. Upper portion micaceous and garnetiferous, lower typical Fordham.
64	I	S. clearance line of bridge	-71.7′	-69.03′	?	"	Grayish, micaceous, banded granitic gneiss, 8′ core, typical.

Bridge No. 3, "Manhattan Bridge'

The cores obtained from the borings made at the site of this bridge are housed together with those from Blackwell's Island Bridge (No. 4) at the Brooklyn terminal of Bridge No. 1 (old Brooklyn Bridge). The location of the different borings is not in every case clear. Nos. 3, 5 and 6 are certainly correctly located. The others are less certain.

The datum M. L. W. is 2.43′ below mean sea level (U. S. datum), M. H. W. is +4.15′.

a) Brooklyn Pier.

Serial No.	Original mark	Location	Depth to rock M. L. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
65	No. 1 (C)	(Brooklyn?)	-89.83′	-92.26′	9.69′	Ford.	Garnetiferous granodiorite, massive.
66	No. 2 (D)	(Brooklyn?)	-86.0′	-88.43′	10.0′	"	Garnetiferous granodiorite.
67	No. 3 (F)	(Brooklyn)	-91.74′	-93.17′	12.12′	"	Granodiorite, typical.
68	No. 4 (E)	" ?	-93.19′	-95.62′	10.0′	"	Granodiorite.
69	No. 5 (A)	"	-89.92′	-92.35′	9.96′	"	Mottled garnetiferous granodiorite, 1-inch core.
70	No. 6 (B)	"	-92.6′	-95.03′	10.0′	"	Garnetiferous granodiorite.
71	111 ?	?	....	....	....	"	Granodiorite, 1-inch core.

(This core apparently belongs here, but this number is not on any of the maps It may replace No. 1 or No. 2 above.)

b) Manhattan Pier.

Serial No.	Original mark	Location	Depth to rock M. L. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
72	No. 1 (D)	N. Y. W. side	-124.9′	-127.33′	4.0′	Manh. ?	Mica schist, 1″ core unusual type.
73	No. 2 (E)	N. Y. E. side	-117.9′	-120.33′	11.0′	Inw'd.	Typical coarse dolomitic limestone, 1″ core, solid crystalline.
74	No. 4 (G)	N. Y. (S. W. cor.)	-96.25′	-98.68′	8.76′	Manh. ?	Very compact mica schist, not typical.

Bridge No. 4. "Blackwell's Island Bridge," or "Queensboro Bridge"

The cores obtained in boring explorations for the piers of the Queensboro bridge are housed with those of Bridge No. 3, at the Brooklyn Terminal of Bridge No. 1 (old Brooklyn Bridge). The system of numbering was such in this case that the same numbers were in part repeated at each pier, and, where other designations or descriptive labels are wanting, the locations are therefore somewhat uncertain. Most of the boxes, however, in which they are stored have some mark indicating the pier represented, for example, "No. 4, N. Y.," or "No. 4, W. Pier" (Blackwell's Island), or "No. 4, East River" (Blackwell's Island) or "No. 4, N. E. cor. Anchorage" (Long Island City) and are therefore more definite.

The whole series was examined, and borings have been arranged in groups representing the different pier locations as fully as can be done with the data at hand. The series as a whole gives entirely satisfactory and consistent evidence as to bed-rock character. The datum is M. H. W. and is 2.34′ above mean sea level (U. S. datum) at Sandy Hook.

a) New York Pier.

Serial No.	Original mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
75		65′ E. of bulkhead	−51.4′	−49.06′	?	....	Not found (No. 1?).
76	2 N.Y.	40′ inside of pier line	−80.4′	−78.06′	?	Manh.	Typical mica schist.
77	3 N.Y.	Bulkhead line	−34.2′	−31.86′	?	"	" " "
78	4 N.Y.	35′ inside bulkhead	−4.0′	−1.66′	?	"	" " "
79		Pier line	−37.9′	−35.56′	...	....	Not found (No. 5?).
80	6 N.Y.	40′ E. of bulkhead	−45.6′	−43.26′	?	Manh.	Typical mica schist.
81	7 N.Y.	25′ N. E. of N. pier	−26.5′	−24.16′	?	"	" " "
82	8 N.Y.	20′ E of N. pier	−31.0′	−28.66′	?	"	" " "
83	9 N.Y.	30′ N. of N. pier	+4.5′	+6.84′	?	"	" " "
84	10 N.Y.	Between No. 7 and No. 9.	−1.7′	+.64′	?	"	" " "

b) West Pier, Blackwell's Island.

Serial No.	Original mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
85	1	W. pier, S. end, water's edge	-17.3′	-14.96′	?	Ford.	Granite gneiss a light colored rock, similar to Yonkers.
86		Center line	-5 0′	-2.66′	?	....	Not found (No. 2?).
87	3	W. pier N. end.	-7.7′	-5.36′	?	?	Mica schist, usual type.
88	4	W. pier, B. I. 30′ N. E.	-2 8′	-.46′	?	Ford.	Granitic gneiss, banded type.
89	5	W. pier, B. I. E side on center line	-9.8′	-7.46′	?	"	Biotite gneiss, banded type.
90	6	W. pier, B. I. 30′ S.	-13 8′	-11.46′	?	Ford.	Mica gneiss, banded type.
91	7	W. pier, B. I. center line, water edge	-8.9′	-6.56′	?	"	Granitic gneiss.

c) East Pier, Blackwell's Island.

Serial No.	Original mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
92	1	E. pier, S. W. corner	+1.3′	+3 64′	?	Ford.?	Biotite gneiss (not characteristic)
93		E. pier, B. I. center line	+2.5′	+4.84′	?	"	Granodiorite, garnetiferous (No. 2?).
94	3	E. pier, N. end	+4.5′	+6.84′	?	?	Mica schist (not characteristic).
95	4	E. pier, N. E. 35′	+1.1′	+3.44′	?	Ford.	Granitic gneiss, banded type.
96	5	Center line E. side	+0 7′	+3.04′	?	....	Core not found.
96	6	E. pier, S. E. 35′	-4.3′	-1.96′	?	Ford.	Granitic gneiss.
97	7	E. pier, B. I. center line water's edge	-7.6′	-5 26′	?	"	Mica gneiss, very micaceous.

d) Long Island City Pier.

Serial No.	Original mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
98	1	"L. I. C." pier head line? or anchorage?	-64.0′	-61.66′	....	Ford.	Biotite schist, rotten and crushed, non-committal.
99	2	....	. ..	....	....	. ..	Not found.
100	3	.. ..	. ..	....	....	....	" "
101	4	N. E. cor. anchorage?	-3.7′	-1.36′	. ..	Ford.	Mica gneiss (schistose type).
102	5	"L. I. C." 60′ W. of pier	-22.4′	-20 06′	....	?	Biotite hornblende schist, streaked. Might be either formation.
103	6	"L. I. C." pier, 60′ S. W. of pier	-22.0′	-19.66′	....	?	Mica gneiss very micaceous.

d) Long Island City Pier. (Continued.)

Serial No.	Original mark	Location	Depth to rock M. H. W.	To rock U. S. datum	Rock penetration	Formation	Variety and remarks
104	7	"Extra hole" between 1 and 6?	-37.4′	-35.06′	....	Ford.	Granitic gneiss. Banded type.
105	8	....	....	....	....	....	Not found.
106	9	....	....	....	....	....	" "
107	10	"L. I. City" 90′ N. E. of pier	-19.7′	-17.36′	....	Ford.	Granodiorite.
108	11	"L. I. City," 60′ S. of pier	+3.5′	+5.84′	....	"	Granitic gneiss, banded.
109	12	"L. I. City" 30′ S.	-9.6′	-7.26′	....	"	" " "
110	13	"L. I. C." N. end of pier	-0.5′	+1.84′	....	"	Biotite gneiss, slightly banded.
111	14	"L. I. C." 50′ N. E.	+5.3′	+7.64′	....	?	Biotite hornblende gneiss (uncertain).
112	15	"L. I. C." 45′ E. Near center line	+7.6′	+9.94′	....	Ford.	Granitic gneiss, banded type.
113	16	"L. I. C." center line	+1.2′	+3.54′	....	?	Mica schist, garnetiferous (uncertain).

Bridge No. 5

This is a projected bridge whose location would be adjacent to the old Brooklyn Bridge No. 1, on the Northeast side. The cores are now in the offices of the Bridge Department, Park Row Building. All are fully labeled. The datum is M. H. W. and is 1.72′ above mean sea level (U. S. datum).

a) Manhattan side.

Serial No.	Original mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
114	A	Between L. I. City Ferry & B'way Ferry	-121.75′	-120.03′	7.75′	Ford. ?	Banded gray mica gneiss, (not typical).
115	B	B'way Ferry	-112.75′	-111.03′	6.05′	" ?	Hornblendic gneiss not typical.
116	C	S. margin of B'way Ferry	-96.90′	-95.18′	6.35′	Ford.	Granitic gneiss, light, striped, 60° (satisfactory Fordham.)
117	D	Between B'way Ferry & Brooklyn Bridge pier	-88.80′	-87.08′	7.45′	" ?	Hornblende rock and granitic gneiss.
118	E	N. end of Brooklyn Bridge pier	-84.40′	-82.68′	9.0′	" ?	Granitic gneiss and pegmatite.

b) Brooklyn side.

Serial No.	Original mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
119	F	Dock St.	-97.5′	-95.78′	7.4′	Ford.	Granodiorite gneiss, garnetiferous.
120	G	At angle in pier-headline N. Y. Dock Co.	-85.25′	-83.53′	4.35′	"	Granitic gneiss, banded, crumpled.
121	I	N. end of B'klyn Bridge pier	-84.7′	-82.98′	10.12′	" ?	Mica gneiss.
122	J.	Between I and Water St.	-77.3′	-75.58′	4.28′	"	Granitic gneiss, striped black and white.

Department of Docks and Ferries

The borings represented in the following list were made by the Department of Docks and Ferries at a large number of pier sites along both the Hudson and East Rivers. Many of them were made twenty to thirty years ago, and they probably constitute the oldest group of such data in the city. The material of the borings represents the muds, sands and gravels of the overburden, as well as the bed-rock. They are all fully labeled, boxed and housed at the yard of the Department of Docks and Ferries, at foot of Twenty-fourth Street and East River. The samples of rocks are all in the form of fragments (not cores) secured from chopping into bed-rock. In most cases they represent but slight penetration of the rock floor, seldom more than two or three feet. In some cases, especially where but a small sample is recovered from an uncommon variety of rock, or from a somewhat decayed bed, it is impossible to determine the formation name. It is more difficult than where solid cores are obtained. In the following tabulation the variety of rock and formational relation as now used are given wherever possible. The original names such as "Granite" and "Syenitic Granite" used chiefly in the sense of crystalline bed-rock are avoided.

The datum used by the Dock Department is Mean Low Water. On Nov. 22, 1898, however, the datum was raised 0.24′. The Board of Water Supply datum (Mean Sea Level at Sandy Hook according to the U. S. Coast and Geodetic Survey) is 2.09 ft. higher than the present Dock Department datum (M. L. W.), and is 2.33 ft. higher than the M. L. W. of the Dock Department as used prior to 1898. As all of the borings tabulated here are older than that date, the latter correction is used in reducing to U. S. datum.

East River Front.

Serial No.	Original mark	Location	Depth to rock M. L. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
123	8	Pier 1, (Old) Battery	-23.99′+	?	0	....	No bed-rock secured.
124	9	Pier 2 (Old) Whitehall St.	-18.77′+	?	0	...	" " " All trap bowlders.
125	10	Pier 6 (Old) Coenties Slip	-20.94′+	?	0	....	No bed-rock secured.
126	11	Pier 9 (Old) between Coenties Slip & Old Slip	-29.93′+	?	0	....	" " "
127	12	Pier 12 (old) Old Slip	-30.95′	-33.28′	3.67′	Manh.	Mica schist, typical.
128	13	Pier 15 (Old) Wall St.	-53 23′	-55.56′	1.70′	"	" " "
129	30	Pier 18 (Old) Maiden Lane	-159.89′	-162.22′	3.50′	"	" " "
130	31	Pier 21 (Old) Burling Slip	-135.91′	-138.24′	2.25′	"	" " "
131	32	Pier 24 (Old) Near Peck Slip	-146.62′	-148.95′	2.75′	"	Garnetiferous and pegmatitic mica schist.
132	33	Pier 28 (Old) Near Roosevelt St.	-98.06′	-100.39′	2.66′	"	Mica schist, typical.
133	34	Between Pier 33 and 34 (Old) near Catherine Slip	-108.79′	-111.12′	2 67′	Ford.	All pieces are fine grained micaceous gneiss, probably Fordham.
134	35	Pier 27 (Old) near Market Slip	-85.28′	-87.61′	2.5′	....	Material not found.
135	36	Pier 41 (Old) Pike Slip	-90.99′	-93.32′	5.16′	Manh.	Mica schist with one limestone fragment.
136	37	Pier 43 (Old) Rutgers Slip	-109.43′	-111.76′	3.17′	"	Mica schist [1]
137	38	Pier 46 (Old) Jefferson St.	-51 0′	-53.33′	2.66′	"	Mica schist, typical.[1]
138	40	Pier 49 (Old) near Clinton St.	-30.86′	-33.19′	3.34′	Ford.	Granite gneiss clear granitic type, similar to Yonkers. Unless it is a large bowlder, the bed-rock is surely Fordham.
139	41	Pier 52 (Old) Gouverneur Slip	-66.56′	-68.89′	1.33′	" ?	Granite gneiss, fine grained, with very small garnets.
140	30	Pier 19 (Old) Fletcher St.	-142.7′	-145.03′	10.65′	?	Material not seen.

[1] Recent exploratory work throws some doubt on the validity of these two borings. It is probable that the material recovered came from bowlders instead of bed rock.

North River Front.

Serial No.	Original mark	Location	Depth to rock M. L. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
141	1	Pier 1 (Old) Battery Place	-35.2′	-37.53′	2.3′	....	Not found.
142	2	Pier 3 (Old) between Battery Pl. and Morris St.	-40.2′	-44 53′	4.8′	?	Only pegmatite and pieces of trap saved.
143	3	Pier 6 (Old) near Rector St.	-42.2′	-44.53′	1.0′	....	Not found.
144	4	Pier 10 (Old) near Carlisle St.	-46.09′	-48.42′	3.0′	Manh.?	Only mica scales recovered mixed with pebbles.
145	5	Pier 39 (Old) Desbrosses St.	-81.36′	-83.69′	1.17′	....	No bed-rock saved.
146	6	Pier 13 (Old) near Albany St.	-40.51′	-42.84′	0.67′	Manh.	Only mica scales recovered
147	7	Pier 18 (Old) Cortlandt St.	-44.35′	-46.68′	1.5′	"	Mica schist.
148	14	Pier 24 (Old) near Vesey St.	-51.08′	-53.41′	1.0′	....	No bed-rock saved.
149	15	Pier 28 (Old) Murray St.	-75.44′	-77.77′	8 91′	Manh.	Mica schist (typical) and granite.
150	16	Pier 30 (Old) Chambers St.	-85.65′	-87.96′	-2.27′	"	Schist, not typical, finer grained than usual.
151	17	Pier 35 (Old) Franklin St	-78.36′	-80.69′	-2 58′	"	Mica schist.
152	18	Pier 38 (Old) Hubert St.	-80.11′	-82.44′	-3.17′	"	" " , typical.
153	19	Pier 42 (Old) near Canal St.	-80.08′	-82 41′	-4.34′	"	" " finer grained than usual.
154	20	Pier 45 (Old) Charlton St.	-36.17′	-38.50′	-2.59′	...	No rock saved.
155	21	Pier 49 (Old) Leroy St.	-85.90′	-88 23′	-8.17′	Manh.	Mica schist, typical.
156	22	Pier 51 (Old) Christopher St.	-124.00′	-126.33′	-1.75′	"	" " "
157	23	Pier ft. of Bethune St.	-157.97′	-160.30′	0.83′	....	No rock saved
158	24	Pier 60 (Old) W. 13th St.	-196.0′	....	0	....	No rock.
159	25	Pier ft. of 23rd St.	-175.16′	-177.49′	5.65′	Manh.	Mica schist, typical.
160	26	Pier ft. of 30th St.	-149.41′	-151.74′	2.58′	" ?	Fragments of quartzite & mica.
161	27	Pier ft. of 38th St.	-84.78′	-87.11′	5.33′	"	Mica schist, typical.
162	28	Pier ft. of 46th St.	-49.79′	-52.12′	4.50′	?	Piece of white granite, either a granite dike or Fordham.
163	29	Pier ft. of 57th St.	-28.88′	-31.21′	5.08′	Manh.	Mica schist, typical.

Pennsylvania, New York and Long Island Railroad Co.

The borings made in the preliminary studies for the tunnels of the East River Division of the Pennsylvania, New York and Long Island Railroad Co. are tabulated approximately in order from west to east, beginning at 7th Avenue and following both 32nd and 33rd Streets to East River. Then the Long Island City side is arranged, beginning at East River between Borden and Flushing Avenues and following the railway to a point 750 feet east of Vanalst Avenue. The figures of depth to rock and rock penetration are taken from the diagrams of borings on the same drawings and are read to the nearest foot. The correction introduced is from mean high water to the U. S. Coast and Geodetic Survey datum, which is 2.72 ft. lower.

East River Division

a) Manhattan Side.

Serial No.	Original mark	Location	Depth to Rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
164	77	32nd St. & 7th Ave E. side.	+33′	+35.5′	12′	Manh.	....
165	80	32nd St., 200′ E. of 7th Ave.	+10′	+12.5′	32′	....	Mica schist 70°.
166	84	32nd St., 410′ E. of 7th Ave.	+15′	+17.5′	10′	....	Not found.
167	90	32nd St., 615′ E. of 7th Ave.	+31′	+33.5′	52′	Manh.	Mica schist 80°.
168	79	33rd St., 100′ E. of 7th Ave.	+22′	+24.5′	14′	....	Not found.
169	93	....	....	....	....	Manh.	Mica schist.
170	83	33rd St., 230′ E. of 7th Ave.	+10′	+12.5′	32′	"	" " , garnetiferous.
171	91	33rd St., 410′ E. of 7th Ave.	+24′	+26.5′	15′	"	Coarse mica schist.
172	92	33rd St., 25′ E. of B'way.	+34′	+36.5′	63′	"	Mica schist.
173	89	33rd St., 240′ E. of B'way.	+15′	+17.5′	9′	"	" "
174	86	33rd St., 450′ E. of B'way	+11′	+13.5′	46′	"	Mica schist.
175	94	33rd St., 200′ W. of 5th Ave.	....	....	....	"	" "
176	81	33rd St., 15′ W. of 5th Ave.	+22′	+24.5′	62′	"	Mica schist and granite.
177	93	32nd St., 15′ E. of B'way.	+27′	+29.5′	56′	....	Not found.

a) Manhattan Side. (Continued.)

Serial No.	Original mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
178	88	32nd St., 220′ E. of B'way.	+24′	+25′	86′	Manh.	Mica schist.
179	87	32nd St., 400′ E. of B'way.	+38′	+40.5′	73′	"	" " 60°.
180	85	32nd St., 650′ E. of B'way.	+6′	+8.5′	20′	"	" "
181	76	33rd St., 105′ E. of 5th Ave.	+38′	+40.5′	7′	"	Banded mica schist (unusual).
182	74	33rd St., 330′ E. of 5th Ave.	+20′	+22.5′	62′	"	Mica schist.
183	78	32nd St. & 5th Ave.	+1′	+3.5′	43′	"	" "
184	82	32nd St., 210′ E. of 5th Ave.	−2′	+0.5′	4′	"	" "
185	75	32nd St. & Madison Ave.	+21′	+23.5′	69′	"	Pegmatite Hornblende Schist and mica schist.
186	72	32nd St., 100′ E. of Madison Ave.	+24′	+26.5′	21′	"	Mica schist.
187	71	32nd St., 285′ E. Madison Ave.	+1′	+3.5′	54′	"	Coarse mica schist.
188	73	33rd St. & Madison Ave.	+26′	+28.5′	20′	"	Mica schist.
189	70	33rd St., 290′ E. Madison Ave.	+41′	+43.5′	89′	"	Light colored mica schist.
190	69	33rd St., 245′ E. of 4th Ave.	+11′	+13.5′	61′	"	Coarse mica schist.
191	66	33rd St. & Lexington Ave.	+17′	+19.5′	12′	"	Mica schist, lumpy.
192	68	32nd St. & 4th Ave.	0′	+2.5′	10′	"	Hornblende schist and garnetiferous mica schist.
193	63	32nd St., 225′ E. of 4th Ave.	+8′	+10.5′	48′	"	Mica schist garnetiferous.
194	67	32nd St., 10′ W. Lexington Ave.	+7′	+9.5′	19′	"	Mica schist 60°.
195	61	33rd St., 110′ E. Lexington Ave.	+6′	+8.5′	72′	"	Garnetiferous mica schist.
196	65	33rd St., 325′ E. Lexington Ave.	−1′	+1.5′	15′	....	Not found.
197	64	32nd St., 100′ E. Lexington Ave.	+1′	+3.5′	66′	Manh.	Mica schist.
198	62	32nd St., 320′ E. Lexington Ave.	−1′	+1.5′	19′	"	" "
199	60	33rd St., 10′ E. 3rd Ave.	+9′	+11.5′	80′	....	Not found.
200	59	33rd St., 210′ E. 3rd Ave.	−6′	−3.5′	11′	Manh.	Mica schist and pegmatite.
201	56	33rd St., 415′ E. 3rd Ave.	−2′	+0.5′	74′	"	Mica schist.

a) Manhattan Side. (Continued.)

Serial No.	Original mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
202	52	33rd St., 25′ W. 2nd Ave.	+1′	+3.5′	16′	Manh.	Mica schist.
203	58	32nd St., 10′ E. 3rd Ave.	+1′	+3.5′	72′	"	Pegmatite and quartzose mica schist.
204	57	32nd St., 215′ E. 3rd Ave.	-11′	-8.5′	26′	"	Mica schist.
205	54	32nd St., 415′ E. 3rd Ave.	-4′	-1.5′	72′	"	Coarse mica schist.
206	53	32nd St., 30′ W. 2nd Ave.	+7′	+9.5′	18′	"	Mica schist, compact.
207	51	32nd St., 10′ E. 2nd Ave.	0′	+2.5′	9′	....	Not found.
208	55	32nd St., 215′ E. 2nd Ave.	+14′	+16.5′	87′	Manh.	Garnetiferous mica schist
209	50	32nd St., 10′ W. 1st Ave.	+14′	+16.5′	104′	"	Mica schist and pegmatite.
210	46	33rd St., 105′ E. 2nd Ave.	-16′	-13.5′	66′	"	Mica schist.
211	48	33rd St., 215′ E. 2nd Ave.	-9′	-6.5′	11′	....	Not found.
212	49	33rd St., 445′ E. 2nd Ave.	-12′	-9.5′	6′	....	" "
213	45	33rd St., 20′ W. 1st Ave.	-11′	-8.5′	80′	Manh.	Mica schist and pegmatite.
214	44	1st Ave. bet. 33rd & 34th Sts.	-10′	-7.5′	17′	"	Mica schist.
215	47	34th St., 100′ E. 1st Ave.	-32′	-29.5′	63′	....	Not found.
216	43	34th St., 190′ E. 1st Ave.	-63′	-60.5′	21′	Manh.	Mica schist.
217	S	33rd St., 10′ E. 1st Ave.	-22′	-19.5′	31′	" (?)	Hornblende rock, unusual.
218	R	33rd St., 100′ E. 1st Ave.	-19′	-16.5′	76′	"	Mica schist.
219	P	No. of 33rd St. 200′ E. 1st Ave.	-63′	-60.5′	43′	"	Mica schist and pegmatite.
220	Q	33rd St., 280′ E. 1st Ave.	-78′	75.5′	28′	"	Mica schist 40°.
221	O	33rd St., 360′ E. 1st Ave.	-97′	-94.5′	23′	"	Mica schist.
222	4	32nd St., 100′ E. 1st Ave.	-4	-1.5′	40′	....	Not found.
223	3	32nd St., 200′ E. 1st Ave.	-52′	-49.5′	43′	....	" "
224	1	....	....	....	....	Manh.	Mica schist.
225	2	32nd St., 340′ E. 1st Ave.	-104′	-101.5′	23′	"	Coarse mica schist.

a) Manhattan Side. (Continued.)

Serial No.	Original mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
226	119	E. side 1st Ave. bet. 33 & 34 Sts.	−32′	−29.5′	53′	?	Black and white gneiss
227	120	Ditto	−50′	−27.5′	6′	Manh.	Hornblende schist 30°.
228	109	20′ E. 1st Ave. bet. 33 & 34 Sts.	−33′	−30.5′	53′	....	Not found.
229	118	40′ E. 1st Ave. bet. 33 & 34 Sts.	−24′	−21.5′	61′	Manh ?	Schists.
230	108	60′ E 1st Ave bet. 33 & 34 Sts.	−23′	−20.5′	68′	Manh.	Close texture mica schist,
231	116	156′ E. 1st Ave. bet. 33 & 34 Sts.	−53′	−50.5′	5′	"	Garnetiferous mica schist.
232	117	156′ E. 1st Ave. bet. 33 & 34 Sts.	−44′	−41.5′	5′	"	"Anthophyllite" and mica schist.
233	115	135′ E. 1st Ave. bet. 33 & 34 Sts.	−54′	−51.5,	5′	"	Mica schist.
234	111	65′ E. 1st Ave. bet. 32 & 33 Sts.	−22′	−19.5′	68′	"	" "
235	114	70′ E. 1st Ave. bet. 32 & 33 Sts.	−34′	−31.5′	52′	"	" "
236	113	90′ E. 1st Ave. bet. 32 & 33 Sts.	−46′	−43.5′	44′	....	Not found.
237	110	100′ E. 1st Ave. bet. 32 & 33 Sts.	−30′	−27.5′	59′	Manh.	Mica schist, close texture.
238	112	120′ E. 1st Ave. bet. 32 & 33 Sts.	−30′	−27.5′	60′	"	Mica schist and pegmatite.

b) Long Island City, between Borden and Flushing Aves. and eastward along the East River.

239	102	90′ W. of Front St., Nassau Slips	−24′•	−21.5′	56′	Ford.	Granite gneiss.
240	105	85′ W. ditto	•−29′	−26 5′	5′	"	" "
241	106	85′ W. ditto	−38′	−35.5′	43′	"	" "
242	99	85′ W. ditto	−26′	−23.5′	54′	"	Granodiorite (light colored)
243	101	105′ W. Front St., So. Nassau Slip	−31′	−28.5′	49′	"	Granite gneiss.
244	104	100′ W. ditto	−27′	−24 5′	53′	"	Granodiorite gneiss.
245	W	170′ W. ditto	−32′	−29.5′	25′	"	Pegmatite and granodiorite gneiss.
246	95	95′ W. ditto	−33′	−30 5′	47′	"	Granodiorite gneiss.
•247	X	85′ W. ditto	−23′	−20.5′	10′	....	Not found.
248	100	45′ W. Front St., Nassau Slip	−22′	−19.5′	58′	Ford.	Granodiorite gneiss.
249	103	45′ W. Front St., Nassau Slip	−24′	−21.5′	56′	....	Not found.

b) Long Island City, between Borden and Flushing Aves. and eastward along the East River. (*Continued.*)

Serial No.	Original mark	Location	Depth to Rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
250	98	45′ W. Front St., Nassau Dock	−24′	−21.5′	56′	Ford.	Not found.
251	97	65′ W. Front St. S. of Nassau Slip	−24′	−21.5′	56′	....	" "
252	107	60′ W. Front St., S. of Nassau Slip	−27′	−24.5′	54′	....	" "
253	96	50′ W. Front St., S. of Nassau Slip	−31′	−28.5′	49′	Ford.	Granite gneiss.
254	T	Pier 475′ W. Front St.	−44′	−41.5′	56′	"	Dioritic banded gneiss.
255	U	370′ W. Front St.	−47′	−44.5′	50′	"	Diorite gneiss and garnetiferous gneiss.
256	V	Pier 270′ W. Front St.	−49′	-46.5′	52′	"	Granodiorite gneiss.
257	X	80′ W. Front St.	−28′	−25.5′	10′	"	Diorite gneiss.
258	7	Front St. No. of Flushing.	−43′	−40.5′	33′	"	Hornblende biotite gneiss, banded.
259	6	Front St. So. of Borden Ave.	−41′	−38.5′	59′	"	Garnetiferous granodiorite.
260	Y	E. side Front St.	−57′	−54.5′	18′	"	Garnetiferous granodiorite and pegmatite.
261	N	L. I. City R. R. Station, 150′ E. Front St.	−43′	−40.5′	13′	"	Diorite and granitic gneiss.
262	M	L. I. City R. R. Station, 260′ E. Front St.	−20′	−17.5′	10′	....	Not found.
263	5	L. I. City R. R. Station, 350′ E. Front St.	−17′	−14.5′	43′	Ford.	Light granite gneiss.
264	8	West Ave. angle	−18′	15.5′	46′	"	Coarse granodiorite.
265	Z	60′ E. West Ave. S. Yard.	−14′	−11.5′	4′	"	Granodiorite and pegmatite.
266	23	160′ ditto	−18′	−15.5′	14′	"	Biotite gneiss striped.
267	24	260′ ditto	−29′	−26.5′	26′	"	
268	25	360′ ditto	−44′	−41.5′	9′	"	Banded granitic gneiss.
269	26	100′ W. Vernon Ave.	−9′	−6.5′	11′	"	Light granodiorite.
270	27	R. R. Yard 70′ W. Vernon Ave.	−21′	−18.5′	16′	"	Foliated granodiorite (marginal).
271	36	Borden Ave. 400′ W. Vernon Ave.	−15′	−12.5′	10′	"	Diorite gneiss.
272	34	Borden Ave. 300′ W. Vernon	−34′	−36.5′	10′	"	Banded gneiss, with pegmatite,
273	33	Borden Ave. 200′ W. Vernon	−34′	−31.5′	7′	"	Granodiorite.
274	31	Borden Ave. 100′ W. Vernon	−43′	−40.5′	7′	....	....

b) Long Island City, between Borden and Flushing Aves. and eastward along the East River. (Continued.)

Serial No.	Original mark	Location	Depth to rock M. H. W.	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
275	32	S. Borden and Vernon Ave.	−19′	−16.5′	7′	Ford.	Granodiorite and pegmatite.
276	28	S. of Borden Ave. at Vernon Ave.	−6′	−3.5′	16′	"	All granodiorite.
277	29	S. Borden, 115′ E. Vernon Ave.	−3′	−0.5′	23′	"	Micaceous granite gneiss.
278	30	S. Borden, 250′ E. Vernon Ave.	−20′	−17.5′	41′	"	Granodiorite and pegmatite.
279	35	Borden Ave. 425′ E. Vernon Ave.	−22′	−19.5′	8′	"	Striped gneiss with granodiorite.
280	38	Bet. Borden & 3rd St. on East Ave.	−3′	−0.5′	10′	"	Pegmatite and diorite gneiss.
281	39	3rd St. 100′ E. East Ave.	−5′	−2.5′	7′	"	All pegmatite.
282	42	3rd St. 230′ E. East Ave.	−8′	−5.5′	19′	"	Granodiorite and pegmatite.
283	41	3rd St. 360′ E. East Ave.	−24′	−21.5′	22′	"	Gneissoid granite, garnet and pegmatite.
284	37	Bet 3rd & 4th Sts. 70′ W. Vanalst.	−22′	−19 5′	15′	"	Granite gneiss, pegmatite and granodiorite.
285	40	L. I. R. R. 250′ E. Vanalst	−23′	−20.5′	7′	"	Granite gneiss.

Miscellaneous and Scattered Borings

The borings tabulated below represent data gathered from examinations of the records and materials of deep wells, plunger elevator holes, tests for foundations and other similar sources. Only those whose materials were personally examined are given a definite formational name. In a few others, such as those at the Navy Yard, in Brooklyn, the published descriptions are so carefully worded that there is little doubt of their meaning. These are all plotted on the accompanying maps.

Astoria Light and Power Co.

Several deep wells at Lawrence Point, on the Long Island side of East River. Manhattan Drilling Co., contractors.

Serial No	Original mark	Location	Depth to Rock	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
286	6	Gas works, Lawrence Point	52′	−34′ ±	1220+[1]	Ford.	Chiefly granite gneiss, with banded gneiss and pegmatite.
287	4	Gas works, Lawrence Point	....	....	350′+	"	Well 400′ deep, granite gneiss.

Governors Island

Two deep wells were bored for water — one near the Hospital at the north margin of the island and one in the moat of Fort Columbus. Material all in fragments (sand) and chips. Housed at the Quatermaster's Department, Governors Island. P. & J. Conlin, contractors.

Serial No.	Original mark	Location	Depth to Rock	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
288	—	The well near the Hospital drilled 1901–02	73′	−60′ ±	1725′	Manh.	Many samples of mica flakes and quartz mica mixture. Coarse mica schist, fine hornblende schist and pegmatite all represented.
289	—	A second well in the moat of Fort Columbus	...	...	300′ ±	....	Well 350′ deep. Rock not seen.

Plunger Elevator Holes on Manhattan

The cores taken from these holes have not in most cases been found complete, but enough in the following ones could be seen to determine the formation. The place where the material can be seen is indicated in each

[1] There are several other shallower wells at this place. No. 286 has been continued and now reaches to a depth of approximately 2000′ with no material change in the rock.

Serial No.	Original mark	Location	Depth to rock	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
290		Trinity Bldg.	....	....	....	Manh.	Typical mica schist showing dip of 60°.[1]
291		The Ansonia, Broadway & 74th St.	....	....	....	"	Mica schist, typical, dip almost vertical.[2]
292		Fifth Ave. Hotel, Fifth Ave. & 23rd St.	....	....	2100′±	"	Mica schist, grayish, fine grained, dip 30°-35°.[3]
293	•	Tribune Bldg., 154 Nassau St	....	....	about 250′	"	Mica schist, typical.[4]

Brooklyn Wells and other Drill Borings

Serial No.	Original mark	Location	Depth to rock	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
294		New Amsterdam Gas Company, Ravenswood	....	. . .	....	Ford.	Banded white and black granitic gneiss, typical Fordham with some pegmatite and micaceous portions.[5]
295		St. George's Hotel, well at 58 Pineapple St.	160′+ below surface.	. . .	240′+	"	Granitic gneiss quartz-biotite feldspar rock. A little garnet.[6]
296		Foot of Atlantic St.	120′ below surface.	....	....	"?	White and black banded granitic gneiss [7]

[1] Specimen of core taken from 335 ft. below the sidewalk is in the American Museum of Natural History.

[2] Specimen of core taken from 127 ft. below the surface is in the American Museum of Natural History.

[3] Diamond drill boring. Specimen of core taken at a depth of 1224 feet is in the collection of the New York Mineralogical Club at the American Museum of Natural History.

[4] Nine holes were made. Only one piece of core was seen. Bed-rock said to be at a depth of 140–160 ft. Piece of core is in the office of the Superintendent of Building.

[5] Three pieces of an 8-inch core were seen at the Ravenswood plant.

[6] The material is wholly in granular fragments due to the method of drilling. A very complete series of samples has been preserved at the hotel. Drilling was in progress when examined. The final depth will be somewhat greater.

[7] Pieces of core from this hole are preserved in the Long Island Historical Museum, together with pieces from three others. All have been given the same number in the museum and therefore it is impossible to be certain that they may not have become interchanged, but by a careful comparison of the four lots and their localities, it seems reasonably sure that this hole is correctly represented by the pieces of banded Fordham gneiss.

Deep Well of the N. Y. Quinine & Chemical Co.

Serial No.	Original mark	Location	Depth to rock	To rock U. S. datum	Rock penetration	Formation	Variety and remarks
297		N. 11th and Berry Sts.	100′ ± from surface.	....	200′+	Ford.	A quartzose granitic gneiss. Quartz biotite feldspar.[1]

East River and the Bay

Serial No.	Original mark	Location	Depth to rock	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
298		St. George's Reef, off New Brighton	....	....	....	Manh.	Mica schist, a coarse pegmatite with a quartz vein.[2]
299		Diamond Reef off the Battery	....	....	....	?	Coarse pegmatite (probably Manhattan).[3]

Recent Exploratory Borings of the New York City Board of Water Supply

(Made since the original study)

The following borings have been made in exploring for condition of bed-rock along the line chosen for the proposed distribution conduit intended to carry the new Catskill water supply. Some of them, those made earliest, have been recorded on the accompanying map. So far as these explorations have gone, they substantiate the interpretation of areal geology and structure offered in this paper. The holes given are all on the Lower East side between the East River and the Bowery.

[1] Samples are all fine granular fragments due to the method of drilling. Nine samples in bottles are preserved in the office of the company.

[2] Three specimens (fragments) are to be seen in the Museum of the Staten Island Natural History Society.

[3] A piece of rock from this reef was seen in the office of the Chief Engineer of the Department of Docks and Ferries.

Serial No.	Original mark	Location	Depth to Rock	To Rock U. S. datum	Rock penetration	Formation	Variety and remarks
300	4	Montgomery & Madison Sts.	84′	−65.5′	4.4′	Ford.	Granodiorite.
301	5	Montgomery & Cherry Sts.	95′	−71′	15.2′	"	Granodiorite.
302	8	Norfolk & Grand Sts.	166′	−30.2′	94.5′	Inw'd.	Coarse crystalline limestone. Upper 60 feet much decayed.
303	9	Foot of Clinton St.	56 8′	−48′	7.6′	Ford.	Granodiorite.
304	15	Ludlow & Delancey Sts.	169′	−133′	44.3′	Inw'd.	Coarse crystalline limestone.
305	25	Eldredge & Delancey Sts.	108′	−68′	8′	Ford.	Gneiss.
306	28	Delancey St. & Bowery	113′	−72′	19′	Manh.	Mica schist.
307	40	Bowery & Stanton St.	101′	−54′	14.5′	"	Mica schist.

The following borings have been made in the East River from the Foot of Clinton Street, Manhattan, to the foot of Bridge Street, Brooklyn.

Serial No.	Original mark	Location	Depth to rock	To rock U. S. datum	Rock penetration	Formation	Variety and remarks
308	21	Distances from Manhattan pier head 225′	....	−65′	16.4′	Ford.	Granodiorite in good sound condition.
309	53	350′	....	−72′	20.2′	"	"
310	32	525′	....	−71′	11.3′	"	"
311	50	695′	....	−76′	20′	"	"
312	34	860′	....	−74′	9′	"	"
313	41	960′	....	−81′	20.8′	"	"
314	39	1070′	....	−67′	30.8′	"	"

The above borings of the Board of Water Supply (Nos. 300 to 314) have all been made since the original report was handed in. They are here included with the original tabulation because of the support they give to the revised geology of Manhattan Island. Boring is still in progress in the Lower East Side district and when completed a more accurate map will be possible.

Summary

A detailed study of all available data bearing upon the question of areal and structural geology of the covered portion of southern Manhattan Island leads to the following general conclusions:

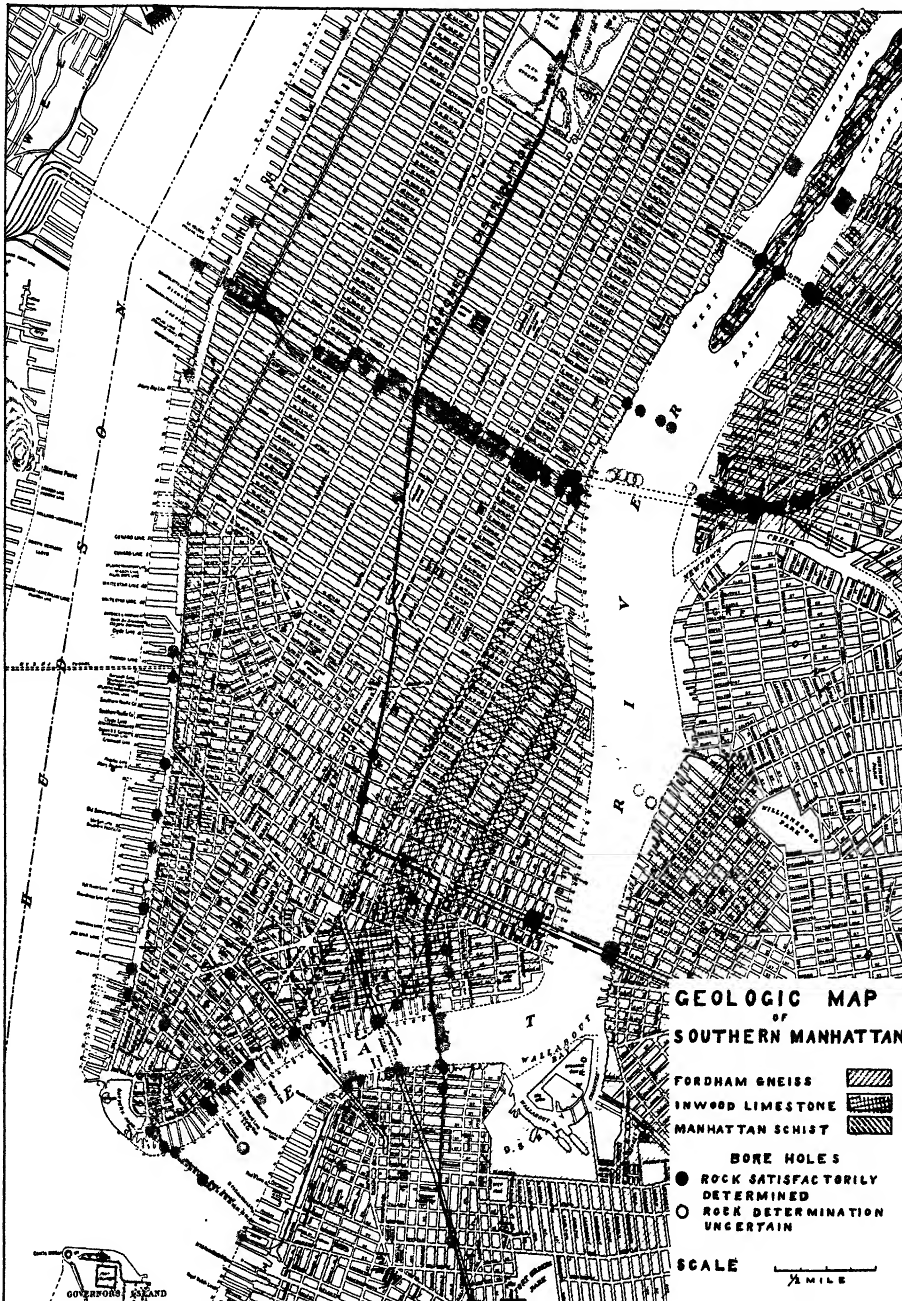
1. All of the typical crystalline rock formations are found within the area.
2. Manhattan Schist forms the rock-floor from the Bowery westward to the Hudson.
3. Between the Bowery and the East River there are at least two belts of Fordham Gneiss, three belts of Inwood Limestone and one other belt of Manhattan Schist.
4. The structure is essentially closely compressed and slightly overturned folds accompanied by some thrust-faulting and a tendency to the development of weak crush zones along the chief planes of movement.
5. The East River, in its great eastward bend around the Lower East Side, is displaced from its pre-Glacial channel by Glacial drift and now flows across perfectly sound rock at a much greater elevation than the channel it once occupied.

It appears therefore that, so far as southern Manhattan is concerned, the present river channels are not controlled by limestone belts, as usually assumed, but the East River is controlled by its drift obstruction.

It will be apparent at once that the configuration of the rock floor is now subject to as extensive revision as the other geologic features.

Areal Map and Geologic Cross Section

The accompanying map and cross section are an attempt to represent these features and are intended to serve as the basis of further correction of the areal and structural detail of southern Manhattan. Neither the map nor the cross section can be considered accurate for depth or dip of formation or exact position of contact, but they are the best interpretation the writer can make of the data now known. Both are presented in the belief that the general features and structures as given will serve a useful purpose in guiding explorations for rock floor and rock condition in the area covered.



GEOLOGIC MAP OF THE SOUTHERN PART OF MANHATTAN ISLAND, N. Y., WITH NEIGHBORING PARTS OF LONG ISLAND.

BY CHARLES P. BERKEY.

Annals of the New York Academy of Sciences,
Volume XIX, Part III, May, 1910.

[ANNALS N. Y. ACAD. SCI., VOL. XIX, No. 12, Part III, pp. 283–401.
May, 1910.]

RECORDS OF MEETINGS

OF THE

NEW YORK ACADEMY OF SCIENCES.

January, 1909, to December, 1909.

BY EDMUND OTIS HOVEY, *Recording Secretary.*

BUSINESS MEETING.

JANUARY 4, 1909.

The Academy met at 8:20 P. M. at the American Museum of Natural History, Vice-President Stevenson presiding in the absence of President Cox.

The minutes of the meeting of December 7, 1908, were read and approved.

The following candidates for Active Membership, recommended by the Council, were duly elected.

Louis Hussakof, Ph. D., American Museum of Natural History,
Arthur F. MacArthur, Buckingham Hotel.

The Academy then adjourned.

EDMUND OTIS HOVEY,
Recording Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

JANUARY 4, 1909.

Section met at 8:15 P. M., Vice-President Stevenson presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Amadeus W. Grabau, SUMMARY OF THE SYMPOSIUM ON GEOLOGIC CORRELATION PRESENTED AT THE BALTIMORE MEETING OF SECTION E OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND THE GEOLOGICAL SOCIETY OF AMERICA.

George F. Kunz announced a new meteorite found near Tonopah, Nevada, weighing 4,000 pounds and believed to have been seen to fall February 18, 1894.

Lawrence Martin described his present work in connection with the Museum of Charleston. The special feature undertaken is to illustrate the mineralogic and geologic material of the Appalachian region and in particular the southern area immediately adjacent.

The Section then adjourned.

CHARLES P. BERKEY,
Secretary.

SECTION OF BIOLOGY.

JANUARY 11, 1909.

Section met at 8:15 P. M., President Cox presiding.

The minutes of the last meeting of the Section were read and approved.

In the absence of the Secretary, Mr. Roy W. Miner was elected Secretary *pro tem.*

A letter was read by the Secretary *pro tem.* from Mr. W. K. Gregory regretfully declining the election to the secretaryship of the Section for the coming year. Dr. Louis Hussakof was then unanimously elected to the office for the same term.

The following public lecture was then offered:

MIMICRY AMONG NORTH AMERICAN BUTTERFLIES

By **Prof. E. B. Poulton** of Oxford University.

The Section then adjourned.

ROY W. MINER,
Secretary pro tem.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

JANUARY 18, 1909.

Section met at 8:15 P. M., Vice-President D. W. Hering presiding.
The minutes of the last meeting of the Section were read and approved.
The following programme was then offered:

O. W. Willcox,	CYLINDROGENITE, A POSSIBLE REPRESENTATIVE OF A CYLINDRICAL (NON-HAUYAN) ORDER OF CRYSTALS.
D. W. Hering,	ORTHOPEDIC PHOTOGRAPHY; NOTES ON THE RECTIFICATION OF DISTORTED PICTURES.
William Campbell,	SOME NOTES ON WESTERN SMELTERS.

SUMMARY OF PAPERS.

Dr. **Willcox** described a remarkable new form of limonite which occurs in the Red Bank sand of the Upper Cretaceous of New Jersey. It occurs normally as perfect cylinders which may be either hollow or solid, terminated at either end by a cone or a hemisphere. It is suggested that they are representatives of a non-Hauyan order of crystals — the cylindrical system as distinguished from the cubical and other systems of the Hauyan order.

Professor **Hering** discussed the defects common in kodak pictures, which arise from badly timed exposures in various conditions of light, resulting in excessive inequalities of light and shade. In printing from such a negative, if the source of light is small, these faults can be corrected to a great extent by holding the printing frame in such a position that the distance to different parts of the negative gives different intensity of illumination. He also considered the distortion of pictures arising from using a short focus lens and holding the camera at an awkward angle. By rephotographing the distorted picture, placing it before the camera at an angle to the axis of the lens, a counter distortion is effected which may rectify the picture. He illustrated the various stages by lantern slides.

Professor **Campbell** spoke on the evolution of the western lead smelters through changes of conditions and improvements in practice. A photograph of the Globe smelter, Denver, showed the location of the main buildings. A plan of the plant showed the location of receiving-tracks, bins for fuel, fluxes and ores, beds, the long-hand-reverberatory, Brown-O'Harra, Brückner and H. and H. roasters, blast furnaces, matte settling reverber-

atories, flues and bag-house, old refineries, etc. A chart of smelting showed course of materials. The handling of raw materials, the method of bedding at different smelters, of roasting, briquetting fine material, the blast furnace, methods of charging, tapping of lead, of matte and slag, the separation of the same and the handling of slag were shown by photographs. Level versus sloping site was shown by contrasting photographs of the Murray plant with those of Leadville, Eilers and others. Two copper smelters were described, the Highland Boy at Bingham with its 20 McDougall and 3 Wethey roasters, 9 reverberatory smelters and 4 converter stands for making blister copper; the Garfield plant with 3 reverberatory and 2 blast furnace smelters and 4 converter stands, the oxide and sulphide mills, beds, etc., and the H. and H. equipment for roasting fine concentrates.

The Section then adjourned.

William Campbell,
Secretary.

SPECIAL MEETING.

January 25, 1909.

The following public lecture took the place of the regular meeting of the Section of Anthropology and Psychology, and the Ethnological Society of America was the guest of the Academy on the occasion:

The Antiquity of Man

By **Albrecht Penck,** of Berlin, Germany.

Edmund Otis Hovey,
Secretary.

BUSINESS MEETING.

February 1, 1909.

The Academy met at 8:15 p. m. at the American Museum of Natural History, President Cox presiding.

The minutes of the meeting of January 4 were read and approved.

The following candidate for Active Membership, recommended by the Council, was duly elected:

Henry A. C. de Rubio, 52 William Street,

and the election ordered to stand as of October 5, 1908.

The Academy then adjourned.

EDMUND OTIS HOVEY,
Recording Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

FEBRUARY 1, 1909.

Section met at 8:15 P. M., Vice-President Stevenson presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Edmund Otis Hovey, NOTES ON STRIATIONS, U-SHAPED VALLEYS AND HANGING VALLEYS PRODUCED BY OTHER THAN GLACIAL ACTION.

Harold J. Cook, IN THE SIOUX COUNTY, NEBRASKA, BONE BEDS IN 1908.

SUMMARY OF PAPERS.

Dr. **Hovey** said, in abstract: The volcanic sand-blasts due to the eruption of Mt. Pelé produced striations and grooves in the material over which they passed that strongly resemble the striations and grooves produced by ice action. The heavily burdened streams of the Soufrière of St. Vincent have carved out rock channels of typical U-shape in the old lava flows of the volcano. The sea cuts back the coast faster than some of the streams erode, producing hanging valleys.

The paper was illustrated by a large number of lantern slides.

Mr. **Cook** traced the successive ascending formations into Sioux County, Nebraska, up the Hat Creek Valley and as far south as the Niobrara River at Agate, Nebraska, beginning with a scene in the typical Oligocene "Big Bad Lands" in South Dakota. Here are the Lower Harrison beds, a phase of the Lower Miocene, in which the well-known Agate Spring fossil quarries are located. Views characteristic of the topography, erosion forms and typical fossils of these beds were shown, and particular attention was paid to the methods of collecting, quarrying and boxing fossils in and about the Agate Spring quarries. Attention was also called to the great number of

scientific institutions represented at these "diggings" and typical views of the camp life of the "bone hunters" were shown.

The slides used in this lecture were a series prepared by Prof. E. H. Barbour, of the University of Nebraska, and it was through his courtesy that it was possible to present them.

Both papers were listened to with much interest by an audience of twenty-five members and visitors.

The Section then adjourned.

Charles P. Berkey,
Secretary.

SECTION OF BIOLOGY.

February 8, 1909.

Section met at 8:15 p. m., Vice-President Chapman presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Bashford Dean,	A New Example of Determinate Evolution.
Raymond L. Ditmars,	Some Interesting Reptiles.
Roy C. Andrews,	Field Observations on the Fin Whales of the North Pacific.

Summary of Papers.

Professor **Dean** had shown in a previous paper that the egg-capsule of the chimæroids at the time of deposition is adapted with singular precision to the needs of the future embryo and had given reasons for the view that this adaptation was orthogenetic rather than selectional, in a legitimate sense. It was now shown that the egg-capsules of various chimæroids could be arranged in an orthogenetic series. In this series the head-and-body portion of the capsule becomes progressively shorter, the tail portion more slender, the lateral web disappears, the opening valve reduces to a smaller area and the respiratory pores of the tail end of the capsule to a longer one. This progressive series is accentuated by the recent discovery of an undetermined capsule from the North Atlantic (?*Chimæra (Bathyalopex) mirabilis*) received by the speaker from Professor Jungersen, of Copenhagen.

Mr. **Ditmars** exhibited a series of living lizards and serpents illustrating

the salient features in the evolution and classification of these groups and said, in abstract: The serpents are undoubtedly derived from lizards. Some of the latter possess grooved teeth, and a series may be arranged among them showing the progressive decline in morphological and functional importance of the limbs. This series begins with such a form as the dragon lizard (*Basiliscus*) with long hind limbs and which, in running, carries its body clear above ground. In other forms the limbs are not as well developed, so that the body rests entirely on the ground (*Heloderma*) or may even be dragged (*Cyclodes*). A connecting link between serpents and lizards was exhibited (*Ophisaurus*). This form looks exactly like a snake, but is a true lizard. In the serpents there are no traces of external limbs, though with the boas and pythons internal ones are present. The jaw is greatly distensible, and true grooved or canaliculated fangs are developed among many. A number of interesting points in the habits of the serpents were brought out.

Mr. **Andrews** gave an account, illustrated by lantern slides, of his experiences while at the whaling stations on the coast of Vancouver Island and southern Alaska. The paper was devoted to a discussion of the habits of some members of the family Balænopteridæ and of the modern methods employed in their capture. Many reproductions of photographs were shown on the screen illustrating the manner of spouting, diving and feeding of these whales. The speaker dwelt especially upon the peculiar manner in which the nasal region is protruded during respiration and upon the attitudes assumed by the animals when diving. The method of feeding and the movements during play were also discussed.

The Section then adjourned.

L. Hussakof,
Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

February 15, 1909.

By permission of Council no meeting was held.

William Campbell,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.*

February 22, 1909.

Joint meeting with the New York Branch of the American Psychological Association.

An afternoon session was held in the Psychological Laboratory of Columbia University, and, after dinner at the Faculty Club, an evening session was held at the American Museum of Natural History.

The following programme was offered:

Edward L. Thorndike,	Correlation of Sensory Discrimination and Intellect.
T. L. Bolton,	Some Observations with the Tapping Test.
Robert MacDougall,	An Application of the Concept of Space Dimension to Experience in Time.
D. S. Miller,	The Knowledge of Temperament from Within and from Without.

A discussion on the "Concept of a Sensation" was participated in by several members.

Summary of Papers.

Professor **Thorndike** reported measurements of the relation of (1) the factor common to accuracy in drawing lines and making up weights, to (2) the factor common to efficiency in scholarship and ability to gain a high rating for intellect from fellow pupils and teachers. This was found to be not 1.00, as stated by Spearman (1904), but between 0.17 and 0.30. Other facts were given contradicting that author's hypothesis that whatever community there is between mental functions is due to one same core of identity present in all.

Professor **Bolton** said, in abstract: My observations were made to determine the value of different lengths of rest between successive trials with the tapping apparatus and also to discover the effect of different pauses upon the daily practise gain in a series of tests. Five trials at tapping were taken with five, ten and twenty seconds rest between successive trials; both hands were used and the tests were continued for twelve to sixteen days with the three reagents and two classes of students of thirty each. The rest pauses for five successive trials were favorable to the amount of work in the order

of twenty, ten and five. The right hand responded more favorably than the left. The average daily gain was greater for trials with five seconds rest than for ten or twenty. The amount of practise gain seems to depend upon the amount of fatigue which the work engenders. The practise gain for the second half of the tests was greater than for the first half, which seems to mean that practise at first consists in overcoming the inhibiting effects of fatigue. The fact that the five-second rest shows a greater average daily gain than the ten or twenty would seem to indicate that in a long series the five-second rest must prove the more favorable to work. When use is made of this test to make comparisons between high and low types of intellect and of normal with abnormal subjects, account must be taken of the degree of practise efficiency in which the normal class of subjects finds itself. Professor Kraepelin's proposition that comparisons must be made between the various rates of practise gain or loss seems to hold good. (These observations were taken and collated by Miss Batty, of the University of Nebraska.)

Professor **MacDougall** said, in abstract: Experience in time is sometimes illustrated by the form of one dimensional space. The latter concept involves, directly or indirectly, such implications as motion in a right line; modification in the rate of such motion and reversibility in its direction; the determinateness of each point in the system and continuity of direction among all pairs of points. This paper is concerned with the development of some of the consequences which would follow from applying this spatial conception to human experience. Free motion, projected in terms of time, would make any point of past or future realizable at will; while the conditions of a right line require that each intervening event find place in the series by which that point is reached. Modification of rate appears in intensive variations of experience as well as in primary acceleration or retardation. Reversal of direction calls for a change in the effective sign of experience. The conception of a right line requires a deterministic theory of conduct, but the relation of each new point to the direction of the preceding series represents the sense of inner consistency, or subjective free-will. The form of experience in time thus realizes, in part, the requirements of the spatial conception, but, in part, its order radically departs therefrom.

Professor **Miller** said, in abstract: In every-day life there are two ways of alluding to a man's knowledge of himself; favorable and unfavorable. We say "only the man himself can answer that question," some question about his motives or thoughts; on the other hand, we say "it would be well if a man could see himself as others see him." To these two attitudes there correspond a philosophical theory and a psychological theory. The philosophical theory is that in the case of consciousness, appearance and reality

coincide; therefore everybody is by the nature of the case acquainted with the contents of his present consciousness. The psychological theory (set forth by Mr. Santayana) is that it is instinct and habit, the constitutional, which determines a man's action and forms his nature; that these can better be observed by the external spectator; that the play of consciousness matters little in comparison. As regards all these it is clear that the philosophical theory is right. A man is acquainted with the contents of his consciousness. But the important thing in knowing his temperament is not what his consciousness is at any moment, but what further consciousness and what acts it will lead to. Thus a man is acquainted with his consciousness, but generally fails to "know himself." As for the psychological theory, it cannot be true that consciousness matters nothing, or even matters little. All consciousness is "impulsive" or motor. All consciousness is, therefore, a force toward action. Consciousness which is prevented by circumstances or stronger impulses from being realized is still a force, though a defeated and buried force. Were the circumstances changed or the paramount impulses altered, the defeated consciousness would have its way. Thus a person who knows his consciousness knows real forces making for action. A person may also observe his own acts and life as truly as an external spectator may observe them. The conclusion is, then, that as between the observer from within and the observer from without it is the inner observer who can see everything. The difficulty for him lies in the many false emphases of consciousness. It is a difficult art for the inner observer really to read the prognostic signs of his consciousness and acts. The advantage of the outer observer is in simplification; all the baffled forces are omitted from his view. But on that very account the outer observer lacks the full material for judgment. It is the inner observer who has them all, could he but master the art of reading the tokens correctly.

Professor **John Dewey** opened the discussion on the "Concept of a Sensation" and distinguished the following meanings of the term:

1. The anatomical — for so it must be called — according to which the sense organ and its central connections are thought of as if dissected out, isolated from the rest of the system, and acting alone. The isolation is unreal; the activity of any part is interlinked with simultaneous activities in other parts and preceding and following activities in the same and other parts. There is never a state of rest, which might serve to isolate the subsequent activity, but everything is really a process of readjustment throughout the system.

2. The physiological or biological conception of a sensori-motor reaction, as frequently stated, is subject to the same criticism: the reaction is not isolated, nor is the stimulus exclusively peripheral, for the existing condition

of the central organs is part cause of the reaction, and this reaction helps determine the stimulus finally operative.

3. A sensation is often conceived in psychology as a "sensory quality," and these qualities are assumed to be primitive and to correspond with elementary processes in the sense organs. This is a good deal of an assumption, since the qualities are known to us only as the apex of a whole system of physiological functioning. We see the color of an object rather than the color itself; we do not start with the sensory qualities and build up the object by putting them together, but we begin with the object, and only reach the sensory quality by an elaborate process of differentiation. The sensory quality is a late achievement, not a primary datum. The "elements" of structural psychology are the last terms of intellectual discrimination.

4. The sensory qualities — as equivalent to Locke's simple ideas — are thought of as the units of knowledge, as the irreducible minimum which cannot be torn off by any amount of criticism of the percept. Locke, however, does not mean, nor would it be true, that all apparent knowledge is made up of simple ideas. He was interested not in tracing the genetic psychology of knowledge, but in providing a logical device for testing knowledge and for appealing against prejudice, dogma and authority. His sensations were not elements of composition but ultimate, and hence elementary, criteria and tests of assurance.

5. The every-day use of the term sensation is illustrated by the phrase "sensational newspaper." Here the sensation is not an element, but a total concrete experience, the essential fact about which is that it is a shock, an interruption of an adjustment which had been running smoothly. While the "sensory qualities" are thoroughly objective, these shock experiences have the true subjective quality since they have, for the instant, no meaning or objective reference. Their character as sensations is exhausted by this absence of reference; there is but one true sensory quality — the quality of shock. From the point of view of logic, the shock experience is valuable, since a state of suspended reference is the basis of the inductive method. Dogmatism, on the contrary, consists in the prompt interpretation of every new shock into terms of some well-established habit. In its true sense, the mental state, or the subjective, is the conscious starting point of a qualitatively new habit.

Professor **F. J. E. Woodbridge,** in following up the discussion, first distinguished two meanings of the term sensation: (1) a reaction of the organism by means of the sense organs; and (2) the sensory qualities of objects. These meanings do not lead to confusion. The confusion arises when we pass to epistemology and inquire into the relation between the sensation

and the thing sensed. We first distinguish between the organism and its environment and then ask at what particular point the sensation arises. We find it impossible to fix the point and are driven to conclude either that there is no sensation, or that all is sensation — conclusions which virtually coincide, since they both leave no meaning to the term. It is clear from this that the term should be banished from epistemology and limited to the empirical uses mentioned above.

Professor **W. P. Montague** offered the following objections to the destructive criticisms of Professor Dewey. Though a sensation does not occur in isolation, yet every perceptual experience has a distinguishable sensory side. We have the same right to distinguish it as we have to distinguish the form and the color of objects, which also never occur in isolation from each other. There is this objection to regarding the sensory qualities as the apex of a long process of development: that, instead of being complex, they seem to be simple in their nature and their external causes seem to be simple processes. It is likely that to simple processes in the external world should correspond simple effects in the organism, such correspondence being relatively independent of evolutionary development. It is also true that the shock experience arises very often from stimuli which are simple, so that there is reason for relating the experience of shock to the sensory qualities, as is done in the conventional use of the term sensation to cover both sorts of fact. The speaker also called attention to a metaphysically puzzling feature of sensation, namely, its "specious present," or seeming occupancy of a segment of past time at each moment of its existence; but this, he thought, was accounted for in the concept of sensation as a form of potential energy into which the kinetic energy of the neural current is transformed at the moment of its redirection in the central nervous system, or even at the moments of its transit through all the various synapses traversed by it.

Professor **R. S. Woodworth** advanced the concept of sensory as distinguished from perceptual centers in the cortex, the sensory centers being those which first received the incoming stimuli from the sense organs. According to this neurological conception, there should be a difference in time between the sensation and the percept, but it must be admitted that it is usually impossible to detect, introspectively, an interval between the first reception of the stimulus and the percept of some object or process. This introspective difficulty has led Professor Pillsbury, in a recent and still unpublished lecture, to the conclusion that there is nothing in consciousness except meanings. From this point of view, it would be honest to give up the concept of sensation in psychology and so speak simply of the stimulus and of the percept. Though these two would be sufficient for most instances of perception, there remain certain objections to giving up the concept of

sensation altogether. There are the pathological cases, in which perception is lost, though sensation remains; there are the shock experiences, in which there is an interval between the first consciousness of the stimulus and the consciousness of its meaning, and there are ambiguous stimuli, like the staircase figure where, in spite of the alternating percepts, there persists throughout the experience an irreducible conscious minimum, which may best be called sensation.

Professor **T. L. Bolton** inferred, from observations upon animals at certain moments, that they distinguish by their bodily attitudes and general conduct differences between the various objects of their environments that have practical bearings for their lives. The attitude assumed in the presence of the object is characteristic of the object. A similar phenomenon may be observed in human beings. This is the fundamental fact in perception, which becomes the feeling of these bodily attitudes that are evoked by an object's presence. Again, we see both animals and human beings acting in the same manner upon objects alike in some respect but very different in others. This likeness is the objective stimulus for, let us say, a sensation of color. Here then is an activity that is characteristic of the objective stimulus of sensation. This resolves the sensation into essentially the same thing as the perception. In the case of the conventional sensation, the stimulus is merely a part of the objective thing which is present and which, in its totality, might elicit an attitude of the kind which we have called perceptual. The sensation and perception both become the feelings of bodily conduct. In perception the whole object is effective in evoking the attitude. The difference is, then, one not in the mental effect but rather in the part of the objective fact that is operative in exciting reactions. They are alike in being mental states of bodily changes, and neither is the effect directly of incoming afferent currents.

The Section then adjourned.

R. S. Woodworth,
Secretary.

BUSINESS MEETING.

March 1, 1909.

The Academy met at 8:17 p. m. at the American Museum of Natural History, President Cox presiding.

The minutes of the meeting of February 1 were read and approved.

The following candidates for Active Membership, recommended by the Council, were duly elected:

J. G. Phelps Stokes, 90 Grove Street,

Chas. Elliot Warren, Lincoln National Bank.

The Recording Secretary reported the following death:

Prof. Wolcott Gibbs, an Honorary Member since 1889.

The Recording Secretary then reported the receipt of letters from Dr. Wilhelm Ostwald and Prof. Edouard Strassburger expressing their gratification at being elected Honorary Members of the Academy.

The Chairman of the Darwin Memorial Committee reported that the centenary of Darwin's birth and the semicentennial of the appearance of the "Origin of Species" had been celebrated on 12 February, according to programme, and that an exhibition illustrating Darwinism and Darwiniana had been opened, to continue for one month, in the Forestry Hall and Darwin Hall of the Museum.

The Academy then adjourned.

EDMUND OTIS HOVEY,
Recording Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

MARCH 1, 1909.

Section met at 8.15 P. M., Professor Kemp presiding in the absence of Vice-President Stevenson.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Thomas C. Brown, STUDIES ON THE MORPHOLOGY AND DEVELOPMENT OF CERTAIN RUGOSE CORALS.

Edmund Otis Hovey, THE SECTION OF THE HUDSON RIVER BED OPPOSITE CORTLANDT STREET, NEW YORK.

Amadeus W. Grabau, SOME REVISED PALEOGEOGRAPHIC CHARTS.

SUMMARY OF PAPERS.

Mr. **Brown** gave a critical study of the structure of Paleozoic corals, tracing relationships and developments through successive species. Lantern slide illustrations from original drawings were shown. Remarks were made

by Professor Grabau, and questions were asked by other members. This paper has been published as pp. 45-97, Vol. XIX, No. 3, Part I, in the Annals of the Academy.

Dr. **Hovey's** material was from the Pennsylvania Railroad Co.'s tunnel. A profile of the Hudson River gorge as indicated by the borings on the tunnel line was exhibited. The slightly shallower nature of this channel as compared to that determined by the McAdoo tunnel borings gave rise to considerable discussion.

Professor **Grabau** exhibited and explained two charts showing studies of probable early Paleozoic distribution of continents and ocean basins and borders.

The Section then adjourned.

CHARLES P. BERKEY,
Secretary.

SECTION OF BIOLOGY.

MARCH 8, 1909.

Section met at 8:15 P. M., Professor Bashford Dean presiding in the absence of Vice-President Chapman.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

W. K. Gregory, GENETIC RELATIONS OF THE INSECTIVORA TO OTHER ORDERS OF MAMMALS.

Max Morse, THE HARPSWELL BIOLOGICAL LABORATORY.

Amadeus W. Grabau, EARLY DEVELOPMENTAL STAGES IN RECENT AND FOSSIL CORALS.

A communication from Dr. L. Hussakof was read, in regard to his application for a grant of $100 from the Newberry Fund to be used in connection with his studies on fossil fishes while abroad. Upon motion of Dr. Raymond C. Osburn, it was voted that the Section approve the application and recommend it favorably to the Council of the Academy.

SUMMARY OF PAPERS.

Mr. **Gregory** reviewed some of the general stages in the evolution of the lower mammals in order to introduce the subject of the genetic relations of the Insectivores. The first stage, lying below the limits of the class Mammalia, is represented by the higher Theriodont reptiles from the Permian

and Triassic of South Africa. The recent discoveries by Broom have brought strong support to the view that these forms are allied to the stem of the Mammalia, from which they differ chiefly in retaining many primitive reptilian characters, notably in the inferior surface of the skull and in the lower jaw. The quadrate, articular and angular bones were smaller in the later than in the earlier Theriodonts, and there is much to prove that the mandibulo-squamosal joint in the mammals is a neomorph, formed concomitantly with the reduction of the quadrate, articular and angular. The mammals may have arisen from some small insectivorous Theriodont allied to *Galesaurus*.

The second stage in the evolution of the mammals is represented by the American Triassic genera, *Dromatherium* and *Microconodon*, both known only from the lower jaw. Here the ascending corono-condylar ramus of the dentary had grown backward into a small but distinct mandibular condyle. The shape of the dentary seemed to indicate that the articular and angular bones might still have been retained in a reduced condition. Resemblances to the Theriodont *Tribolodon* of South Africa, in connection with the exceedingly primitive features of the dentition, supported the inference that these minute insectivorous forms were near the border land between reptiles and mammals

The third stage is represented to some extent by the Monotremes of Australia. In the existing genera the skull is very aberrantly modified, but they have retained oviparous habits and a very lowly type of brain, while the shoulder girdle, humerus, carpus, tarsus, etc. are of modified Theriodont type. Although not known before the Pleistocene, the Monotremes are thus of an exceedingly archaic type which probably dates back in many characters to the Triassic.

The fourth stage is typified by the celebrated genus *Amphitherium* from the Middle Jurassic (Stonesfield Slate) of England, known only from the lower jaw. The dental formula could give rise by reduction to either the Marsupial or the Placental types, the cheek teeth are very primitive both in form and number, the angle in one species is partly inflected; the habits were probably insectivorous.

The fifth stage is partly typified by the smaller insectivorous Marsupials, especially the Murine Opossum (*Marmosa*) of South America. All Marsupials have departed from the primitive Marsupio-Placental stem in the partial suppression of the milk dentition, loss of premolar 2, predominence of the yolk-sack placenta, peculiar modifications of the reproductive organs, etc. On the other hand the Polyprotodont Marsupials, especially *Marmosa*, retain certain primitive characters which have been more or less lost in the Placentals, especially the primary adaptations for arboreal habits, the general architecture of the skull, the characters of the pelvis, astragalus, etc.

The sixth stage may be reconstructed by a comparative study of the Eocene Creodonts and the Tertiary and modern Insectivores, by subtracting from each known family its well marked lines of specialization, thus leaving a residue of primitive mammalian characters. This generalized Placental type may have attained its distinctive features in the Jurassic or Cretaceous. From the contemporary Marsupials it was separated by the retention of a complete milk dentition and by certain details of the skull. In general form and proportions it may have resembled the above mentioned Marsupial *Marmosa*, especially in the skull, but in the skeleton it approximated rather towards the earliest Eocene Creodonts and Insectivores and, in many characters, towards the modern Tree Shrews (*Tupaiidæ*). From such a generalized Cretaceous Insectivore-Creodont type all the other orders of Placentals may have been directly or indirectly derived, but the details of this great adaptive radiation must be reserved for another occasion.

Mr. **Morse** showed a series of slides illustrating the Harpswell region and environs. The laboratory was founded by Dr. J. S. Kingsley in 1898 in the little fishing village of South Harpswell, Maine, eighteen miles from Portland. The immediate region is rich in interesting forms of animal and plant life which are peculiarly adapted to the use of investigators. The old Tide-mill collecting ground and samples of some of the more important animals and plants to be found there were illustrated. The geology of the Harpswell region has not been worked up and this presents interesting questions, especially in glacial geology. The speaker pointed out the advantages offered by the laboratory over those of our other marine stations.

Professor **Grabau** said, in abstract: Paleozoic corals show in their septal development a fundamental tetrameral plan. This is persistent in the earliest known forms but becomes masked in later species by the secondary assumption of radiality. The development of the mesenteries in modern Hexacoralla shows a similar order of appearance. Pairs of mesenteries develop in succession in bilateral disposition. From the position of the muscle strands they are either dorsads (musculature turned dorsal-ward), or ventrads. The first and second pairs are ventrads. The third (ventral directive) is a pair of dorsads, the fourth (dorsal directive) is a pair of ventrads. The fifth and sixth pairs are dorsads forming with the first and second pairs four false pairs of "braces." After that the mesenteries appear in compound pairs, a pair of dorsads and one of ventrads appearing simultaneously. Thus in the corresponding inter-mesenterial spaces a brace of new mesenteries appears, the order being comparable even in detail to the order of appearance of the septa in the Paleozoic Tetracoralla.

The Section then adjourned.

L. Hussakof,
Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

March 15, 1909.

Section met at 8:15 P. M., Vice-President Hering presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

C. C. Trowbridge, New Laws of Gas Phosphorescence.
William Campbell, Notes on the Structure of Hardened Steel.

Summary of Papers.

Dr. **Trowbridge** gave a detailed description of the apparatus he had designed for the measurement of gas phosphorescence and then showed the results obtained in the form of plotted curves.

Professor **Campbell** first spoke of the work that had been done in trying to unravel the constitution of hardened steel; of the fight among the authorities as to the right of giving names to the constituents or structures observed. Then by means of lantern slides he showed typical photographs of hardened low carbon and high carbon steels, showing austenite, martensite, troostite, etc. and afterwards discussed the work of Benedicks on rate of quenching.

The Section then adjourned.

William Campbell,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

March 22, 1909.

Section met in conjunction with the American Ethnological Society at 8:15 P. M., Vice-President Fishberg presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

F. Grendon, Anglo-Saxon Charms.
Franz Boas, The Theory of Correlation.

Summary of Papers.

Mr. **Grendon** illustrated by examples of Anglo Saxon charms, of which he has made a large collection, the prevailing characteristics of the spells and the various classes which were in use. He recognized five classes: (1) exorcism of diseases or disease-spirits; (2) herbal charms; (3) charms for transferring disease; (4) amulet charms; and (5) charm remedies. The attitude of the early Christian church to heathen charms was briefly described and some notice taken of Christian elements which appear in the charms. Mr. Grendon's work appears in full in the *Journal of American Folk-Lore*, volume 22, pp. 105–237, June, 1909.

Professor **Boas** brought forward some new methods for studying correlations, especially for examining the correlations among fraternities and other multiple and also average correlations. He also derived formulæ for determining the correlation between phenomena which are not measured but only counted.

The Section then adjourned.

R. S. Woodworth,
Secretary.

BUSINESS MEETING.

April 5, 1909.

The Academy met at 8:15 P. M. at the American Museum of Natural History, President Cox presiding.

In the absence of the Recording Secretary, Dr. Charles P. Berkey was elected Secretary *pro tem.*

The minutes of the meeting of March 1 were read and approved.

The following candidate for Active Membership, recommended by the Council, was duly elected:

Edward H. Squibb, M. D., 148 Columbia Heights, Brooklyn, N. Y.

The Academy then adjourned.

Charles P. Berkey,
Secretary pro tem.

SECTION OF GEOLOGY AND MINERALOGY.

April 5, 1909.

Section met at 8:15 P. M., President Cox presiding in the absence of Vice-President Stevenson.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

George F. Kunz, The Two Greatest Diamonds of History; Their Finding and Ultimate Disposal.

W. D. Matthew, Bulletins on Geologic Correlation through Vertebrate Paleontology by International Coöperation. Nos. 1 and 2.

At the conclusion of the programme a notice was read announcing a joint meeting of geologists of the northeastern states under the auspices of the Philadelphia Academy of Sciences, April 23–24, 1909.

A resolution was then presented by Dr. A. A. Julien as follows: "The Geological Section of the New York Academy of Sciences would respectfully petition the Council of the Academy to send an immediate protest to the Assembly Cities Committee of the Legislature at Albany against the Francis Bill for the occupation of the Arsenal site in Central Park by the National Academy of Design or any other society." A motion to adopt this resolution was discussed at some length by Dr. Kunz and Professor Grabau. On vote the resolution was adopted.

Summary of Papers.

Dr. **Kunz** gave a very interesting account of the finding of the Excelsior and the Cullinan diamonds and called attention to their special characters. Models of these diamonds and several lantern views of the localities where they were found, as well as of the stages that they passed through in reaching their present condition as polished gems, were shown. To a question about the recent developments in the Arkansas diamond locality, Dr. Kunz replied that arrangements were being made to work the mine and that over five hundred stones had been found.

Dr. **Matthew** explained the scope and nature of these researches and gave the names and authors of the Bulletins as follows:

(a) Bulletin No. 1. Outline of Plan and Scope of the Correlation Work

Proposed. By Henry Fairfield Osborn, Chairman, and W. D. Matthew, Secretary, of the Vertebrate Section of the International Correlation Committee of the National Academy of Sciences.

(b) Bulletin No. 2. Fossil Vertebrates of Belgium. By Louis Dollo. (Translated by W. D. Matthew.)

(c) Bulletin No. 3. Observations upon the Cretaceous and Tertiary Section of the Argentine Republic. By Dr. Santiago Roth. Abstract with critical notes by W. D. Matthew.

The Section then adjourned.

Charles P. Berkey,
Secretary.

SECTION OF BIOLOGY.

April 12, 1909.

Section met at 8:15 p. m., Professor Charles L. Bristol presiding in the absence of Vice-President Chapman.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Henry F. Osborn, Final Report on the Exploration of the Fayûm in 1907.

Chas. R. Stockard, Studies on Tissue Growth.

Henry E. Crampton, The Partulas of the Society Islands and the Problem of Isolation.

Summary of Papers.

In the absence of Prof. Osborn a report on the work in the Fayûm region was given by Mr. Walter Granger of the American Museum of Natural History. The speaker stated that the collection, consisting of nearly 600 specimens, obtained by this expedition had been prepared. It proves to contain representatives of nearly all the mammalian forms known from this region together with several new genera and many new species. Among the new forms are rodents, recorded for the first time from these beds, and two peculiar small forms of uncertain ordinal position.

The collection contains many fine specimens of described species which add much to the previous knowledge of these interesting mammals. Doubt

was expressed as to the relationships of the genus *Megalohyrax* to the Hyracoidea and *Mœritherium* to the Proboscidia. The speaker stated that the collection of 1907 is being increased through the efforts of a representative maintained in the Fayûm.

By charts and slides the geology of the region was illustrated, also the important topographic features and the methods employed in prospecting and collecting the fossils.

Professor **Crampton** presented some of the general results obtained during investigations in 1906, 1907 and 1908, dealing with the variations and distribution of terrestrial snails of the genus *Partula*, inhabiting the Society Islands. The geographical and physiographical conditions were described. The islands of this group are volcanic peaks of a partly submerged range; these peaks occur sometimes in contact as in the double island of Tahiti, while others have greater or less distances between them. It is, therefore, possible to correlate the specific differences between the snails of different cones with the geographical proximity of the cones. As each island peak is furrowed more or less regularly by valleys, and as the snails occur only in the moist bottomlands of these valleys, it is possible to correlate the degree of resemblance between the species of neighboring valleys with the degree of geographical isolation. In brief, such correlations are extraordinarily close, as in the case of the classic Achatinellidæ of the Hawaiian Islands described by Gulick.

The varieties of snails occurring in different valleys of one and the same island, or in different islands of the group, cannot be regarded as produced by different environmental circumstances. Several illustrations were given which established this conclusion. The phenomena of mutation were observed in several islands. Finally the rôle of natural selection was determined to be a much restricted one in the case of these snails.

The Section then adjourned.

L. Hussakóf,
Secretary.

SECTION OF ASTRONOMY PHYSICS AND CHEMISTRY.

April 20, 1909.

By permission of Council no meeting was held.

William Campbell,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

APRIL 26, 1909.

Section met in conjunction with the New York Branch of the American Psychological Association at 4 P. M. at the Psychological Laboratory of Columbia University and at 8:15 P. M. at the American Museum of Natural History, Prof. J. McK. Cattell presiding in the absence of Vice-President Fishberg.

The following programme was offered:

Afternoon Session.

Sidney W. Ashe, THE REACTION OF THE PUPIL TO COLOR.
David E. Rice, STUDIES IN VISUAL ACUITY.
J. Carleton Bell, STUDIES IN COLOR STEROSCOPY.

Evening Session.

R. S. Woodworth, HERMANN EBBINGHAUS.
Charles H. Judd, THE RELATION OF MOVEMENT TO CONSCIOUSNESS.

SUMMARY OF PAPERS.

Mr. **Ashe** presented the results of a study of the reaction of the pupil to color. A concave mirror was so adjusted that a person could read in it the diameter of his own pupil, into which was then thrown light of known wave-length and intensity. He found that for equal luminosities of light, as determined by the flicker photometer, the pupil assumes a different diameter according to the color, having the greatest width for red light, next for white, then for green and then for blue. The width assumed varies with the excentricity of the light stimulus, and the effects of the different colors change unequally in passage to peripheral vision, so that the difference in the size of the pupil, as between white and green lights of equal luminosity, becomes greater as the light becomes more excentric.

Mr. **Rice** reported on his studies in visual acuity, in which he has determined the effects of differences of luminosity and of color on the legibility of standard letters.

Professor **Woodworth** read an appreciation of the work of Professor Hermann Ebbinghaus, late professor of philosophy in the University of Halle.

In the absence of Professor **Judd,** his paper was read by Dr. Bingham. Professor Judd held that the importance of motor discharge to mental phenomena could not be properly gauged by the introspection of adults. Attention is apt to be engrossed by the sensory presentation, and the importance of the motor discharge is overlooked. In everything, however, which concerns the organization of experience, the reaction of the individual to his environment is the determining factor. The organization of the sensory material into such forms as the space and time orders depends on the demands of limited internal organization and unlimited external sensory material. This view is in line with that of Sherrington that the development of motor processes is the keynote of all nervous organization; and also with that of Dewey that the child's development is not a sensory by a motor and reactive growth; and with that of Wund regarding the importance of language — which is a form of reaction — in all mental life.

This paper was discussed by several, among whom Professor T. L. Bolton urged that Professor Judd had not gone far enough in his emphasis on the motor side of experience. Instead of assuming at the start the existence of sensations and of the whole sensory field and using the motor elements simply for organization and elaboration of this material, it is possible to begin by showing that all sensory processes have a motor side, which gives meaning to the sensory. A sensation is what it is because of motor reactions, and a percept is constituted by the bodily attitude which the stimulus provokes. The sensory is not more primary nor more rich than the motor, but the two are closely correlated, being, in fact, but different modes of conceiving the experience.

The Section then adjourned.

R. S. Woodworth,
Secretary.

BUSINESS MEETING.

May 3, 1909.

The Academy met at 8:15 p. m. at the American Museum of Natural History, Vice-President Stevenson presiding in the absence of President Cox.

The minutes of the meeting of April 5 were read and approved.

The following candidate for Active Membership, recommended by the Council, was duly elected:

W. M. Carlebach, 136 West 86th Street.

The Recording Secretary reported the following death:

Alfred R. Wolff, Active Member since 1898.

The Recording Secretary then reported the gift by President Cox of certain portraits of Charles Darwin, pages of the original manuscript of "The Descent of Man" and the naturalist's diary kept while on the Beagle. On motion, the Academy instructed the Recording Secretary to transmit to President Cox an expression of appreciation of his generous gift.

The Academy then adjourned.

EDMUND OTIS HOVEY,
Recording Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

MAY 3, 1909.

Section met at 8:15 P. M., Vice-President Stevenson presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered.

Marshall H. Saville, OBSERVATIONS ON RECENT GEOLOGIC CHANGES AFFECTING THE COAST OF ECUADOR.

H. D. Kinney, A NEW ANTHOPHYLLITE OCCURRENCE ON MANHATTAN ISLAND.

Alexis A. Julien, THE MOULIN POTHOLES WITHIN NEW YORK CITY.

SUMMARY OF PAPERS.

Professor **Saville's** paper was illustrated with many lantern slides showing the coastal conditions and sedimentation structures and remains of human handiwork, and the author emphasized the wide distribution of these remains and pointed out the importance of a thorough geologic study of their association as a necessary step in unraveling an interesting prehistoric chapter. Remarks were made on the paper by Professor J. F. Kemp and Professor A. W. Grabau, and further explanatory remarks were made by Professor Saville.

Mr. **Kinney** described, in his paper, an occurrence at One Hundred and Thirtieth Street, New York City, where an original basic intrusion has by metamorphism and alteration developed an interesting variety of petrographic character. The author further stated that as in most other similar cases this one also shows little or no anthophyllite in the specimens studied, and the name is not exactly applicable, but there are other amphiboles in abundance. A general petrographic description was given, and remarks were made by Dr. A. A. Julien and Dr. Charles P. Berkey.

Dr. **Julien** described several "moulin" potholes in addition to the enumeration of the commonly known cases of this type of erosional feature within New York City. Remarks were made by Dr. Berkey on the St. Croix Dalles occurrence, by Professor Stevenson on other observations and by Dr. Hovey on occurrences in Mexico.

The Section then adjourned.

Charles P. Berkey,
Secretary.

SECTION OF BIOLOGY.

May 10, 1909.

Section met at 8:15 p. m., Vice-President Chapman presiding.

Mr. Frank M. Chapman was elected Secretary *pro tem.* in the absence of the secretary.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Charles L. Bristol, *Bufo agua* in Bermuda.

Frank E. Lutz, The Relation between the Taxonomic Characters of Crickets (*Gryllus*) and the Environment.

Ernest E. Smith, What are Deleterious Ingredients of Food?

Summary of Papers.

Dr. **Lutz** said, in abstract: The species of *Gryllus* are distinguished chiefly by the actual and relative sizes of the ovipositor, posterior femora, wings and tegmina. The length of the ovipositor is correlated with the character of the soil, being longer on sand soils than on the firmer ones. This was probably brought about by selection destroying the eggs which are not deeply placed in loose soil. The length of the wings seems to be a function

of three variables: ancestors, heat and moisture. Increased heat and moisture is accompanied not only by an increased percentage of the long-winged dimorphs but by a greater wing length of the short-winged group. No relation has been discovered between the size of the posterior femora and the environment. These conditions bring about marked differences between the crickets in different habitats, and these differences are of "specific" rank.

Dr. **Smith** said, in abstract: Food itself is deleterious if ingested in sufficient quantity. This is not an essential quality of food but one dependent on the quantitative relation. Any ingredient added to food is deleterious in the quantitative sense precisely as food itself is. The statement of the Food and Drugs Act, June 30th, 1906, "an article shall be deemed to be adulterated, in the case of food, if it contain any added poisonous or other added deleterious ingredient which may render such article injurious to health" is to be interpreted as referring to ingredients that are essentially deleterious. Substances that serve a useful purpose in amount widely separated from the quantity that may produce injurious effects are not essentially deleterious, even though they may become deleterious by abuse of the quantitative relation.

The Section then adjourned.

Frank M. Chapman,
Secretary pro tem.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

May 17, 1909.

Section met in conjunction with the Physics Club of New York at 8:15 p. m., Vice-President Hering presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Demonstration.

H. C. Cheston, Apparatus for determining the heat of vaporization of water, using electric current to provide the heat.

PAPERS.

Charles G. Cook, THE RELATION OF MODERN THEORIES OF MATTER TO THE TEACHING OF PHYSICAL SCIENCE.

Frank B. Spalding, APPARENT LOCATION OF OBJECTS UNDER WATER.

R. W. Sutliffe, A NEW CONSTRUCTION OF THE D'ARSONVAL TYPE MEASURING INSTRUMENT.

D. W. Hering, THE DISTORTION AND OSCILLATION OF HELICAL SPRINGS.

William Campbell, SIMPLE EXPERIMENTS IN MATALLOGRAPHY FOR SCHOOL WORK.

SUMMARY OF PAPERS.

Professor **Hering** presented a continuation of an earlier paper on helical springs. In this he discussed the effect which the mass of the spring has on the period of oscillation. It was shown that this effect is the same as would be due to the suspension of a mass whose moment of inertia with reference to the fixed end of the spring is equal to the moment of inertia of the spring itself about the same point, and comparisons were made between periods determined from this theory and those actually observed.

Professor **Campbell** described the simple apparatus necessary to prepare and examine metals and alloys under the microscope. For elementary work, wrought iron, mild steel, rail steel, tool steel and white and gray cast iron could be examined using the material worked with in the forge, foundry and machine shop. Then a few simple alloys such as lead solders or hard lead (antimony lead alloys) could be prepared and finally a brass and a bronze examined. The whole work outlined was to explain the properties of the material used in the shop-work.

The Section then adjourned.

WILLIAM CAMPBELL,
Secretary.

BUSINESS MEETING.

OCTOBER 4, 1909.

The Academy met at 8:28 P. M. at the American Museum of Natural History, President Cox presiding.

The minutes of the meeting of May 5 were read and approved.

The following candidates for Membership, recommended by the Council, were duly elected:

Active Membership:

F. Wilton James, 434 Warren St., Hudson, N. Y.

Associate Active Membership:

G. Sherbourne Rogers, Columbia University.

The following amendment to Chapter 5, Paragraph 1, of the By-Laws as the third sentence of that paragraph was proposed in writing by Messrs. Cox and Hovey: "Failure to pay the required dues within three months after notification of election has been sent, shall render the election void."

The Recording Secretary reported the following deaths:

Simon Newcomb, Honorary Member since 1891,
Prof. Samuel W. Johnson, Corresponding Member since 1876,
T. Mellard Reade, Corresponding Member since 1888,
T. W. Pearsall, Active Member since 1907,
W. Wheeler Smith, Active Member since 1905.

President Cox then reported that he had attended the Darwin Memorial Celebration of the University of Cambridge, England, 22–24 June, as official delegate of the Academy and presented the greetings of the Academy.

Professor Britton then described the Darwin Exhibit at the British Museum.

The Academy then adjourned.

EDMUND OTIS HOVEY,
Recording Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

OCTOBER 4, 1909.

Section met at 9:03 P. M., Professor Kemp presiding in the absence of Vice-President Stevenson.

Dr. E. O. Hovey was elected Secretary *pro tem* in the absence of Dr. Berkey.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Amadeus W. Grabau, PRESENT STATUS OF THE GENESEE RIVER PROBLEM.

The Section then adjourned.

EDMUND OTIS HOVEY,
Secretary pro tem.

SECTION OF BIOLOGY.

OCTOBER 11, 1909.

Section met at 8:15 P. M., Professor N. L. Britton presiding in the absence of Vice-President Chapman.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Miss Nina L. Marshall, COMMON MUSHROOMS AND HOW TO KNOW THEM.

Miss **Marshall,** who is the author of a popular book on mushrooms, exhibited a series of beautifully colored slides illustrating the principal types of mushrooms. She dwelt especially on the ecology of the different forms and on their economic importance to man.

The Section then adjourned.

L. HUSSAKOF,
Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

OCTOBER 18, 1909.

Section met at 8:15 P. M., Professor Hering presiding.

The minutes of the last meeting of the Section were read and approved.

Prof. J. F. Kemp moved and Dr. C. C. Trowbridge seconded the nomination of Prof. W. Campbell for Vice-President of the Academy and Chairman of the Section. Carried.

The following programme was then offered:

Edward Thatcher, SOME PRINCIPLES OF ART METAL WORK.

William Campbell, ON THE STRUCTURE AND CONSTITUTION OF ALLOYS AND METALS USED IN THE ARTS.

D. W. Hering, WAVE LENGTH OF LIGHT BY NEWTON'S RINGS.

SUMMARY OF PAPERS.

Mr. **Thatcher** gave an outline of the methods followed in Art Metal Work at Teacher's College, Columbia University. Starting with the making of a

simple design on copper by hammering or etching, he discussed the more intricate work of hammering and then took up soft and hard soldering and the building up of jewelry, etc.

Dr. **Campbell** described and showed by lantern slides the structures of pure metals and the changes brought about by rolling, hammering and annealing. Then he showed the structure and constitution of the soft soldars, brasses, bronzes, german silvers, the coinage and jewelry alloys and finally some of the white metals for castings, comparing structure with physical properties.

Professor **Hering** showed an experiment on Newton's rings. A pair of circular glass plates were fitted into a holder with binding screws whereby the pressure could be changed at will. The rings therefrom were projected on the screen by the lantern, and then moved by changing the pressure.

The Section then adjourned.

William Campbell,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

October 25, 1909.

Section met in conjunction with the American Ethnological Society at 8:15 p. m., Vice-President Fishberg presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Robert H. Lowie, The Age-Societies of the Plains Indians.
Leo S. Frachtenberg, Notes on Coos Ethnology.

Summary of Papers.

Dr. **Lowie** distinguished between the genuine feasting age-societies of old, middle-aged and young men found among the Omaha and the ceremonial age-groups of the Arapaho, Gros Ventre, Blackfoot and Village tribes. The latter do not seem to correspond to fundamental age divisions, so that some other character of as yet problematic character must be assumed to have entered into their development. The lecturer insisted that these ceremonial organizations cannot be classified on the basis of single char-

acteristics, even though these involve the ostensible conditions of membership, but that it is necessary to isolate well-marked single features and to study their diffusion and the various combinations into which they enter.

Mr. **Frachtenberg** stated that the Coos Indians of northwestern Oregon form an independent linguistic stock. Their language may be subdivided into two distinct dialects, called Hánîs and Mî'luk. The Mî'luk dialect is extinct, while Hánîs is still spoken by about thirty individuals living between Acme and Florence, in Lane County, Oregon. The long intercourse between the Coos Indians and the white settlers has effected a total assimilation of the "Red Man." To such an extent is this that the Coos show no traces whatever of the ancient Indian mode of life. There are, however, a few individuals who still remember phases of that life. The information obtained from these individuals tends to show that the ancient Coos customs varied little from those of the other tribes of the Pacific coast. The most important differences may be summed up as follows: The Coos were a peaceful tribe, seldom resorting to war, and never practised scalping. Flattening of heads was unknown among them, as was likewise tattooing. Their implements and utensils show an absolute lack of decorative art, and their festivals were devoid of any ceremonial significance.

The Section then adjourned.

R. S. Woodworth,
Secretary.

BUSINESS MEETING.

November 1, 1909.

The Academy met at 8:15 p. m. at the American Museum of Natural History, Vice-President Stevenson presiding in the absence of President Cox.

In the absence of the Recording Secretary, Dr. Charles P. Berkey was elected Secretary *pro tem.*

No business being presented, the meeting, by the request of the President and Recording Secretary, was adjourned to 8 November.

Charles P. Berkey,
Secretary pro tem.

SECTION OF GEOLOGY AND MINERALOGY.

November 1, 1909.

Section met at 8:15 p. m., Vice-President Stevenson presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Arthur Hollick, NOTES IN CONNECTION WITH SPECIMENS RECENTLY OBTAINED FROM THE SERPENTINES OF STATEN ISLAND.

Alexis A. Julien, PETROGRAPHIC NOTES ON CERTAIN ROCKS FROM STATEN ISLAND.

F. J. Fohs, FLUORSPAR DEPOSITS OF KENTUCKY.

Professor **Kemp** announced the receipt of a specimen from Franklin Furnace, New York, containing two new minerals for that locality — native silver and chalcocite. Attention was called to the remarkable list of mineral species credited to this place.

SUMMARY OF PAPERS.

Dr. **Hollick** said: The so-called serpentine or soapstone area of Staten Island, represented by the range of hills extending from the shore at New Brighton to the Fresh Kills marshes near the center of the Island at Richmond, has been described and discussed so frequently that only brief reference here to its general surface features is necessary.

The trend of the hills is approximately northeast and southwest, with a curve toward the south. The eastern and southern borders of the area are well defined by steep slopes, which in places are almost perpendicular escarpments of bare rock. The outcrops, however, are for the most part hidden and their outlines modified either by talus accumulations or by glacial drift. Only a limited portion of the area, on the southern flank of Todt Hill, is south of the terminal moraine. Toward the north and west, the surface is an irregular slope to tide water, and the limits of the boundary between can only be inferred. The rock is everywhere covered with glacial and recent surficial deposits, except in certain stream beds. Elsewhere, however, it has been exposed in sewer, street and other excavations, and its presence nearby in other places is indicated by fragmentary surface material. On theoretical grounds, the northwest boundary is assumed to be approximately parallel with and close to the eastern edge of the trap ridge which extends from Port Richmond to Linoleumville.

This area has been under observation for a longer period than any other local geological formation, and yet we know as little to-day in regard to its exact stratigraphic relations as was known when it was first studied. The contact between it and the adjacent formations, other than the overlying surficial deposits, has never been observed or determined, so far as any records show, although attempts have been made to indicate the probable

relations by several of those who have investigated the geology of the region.[1] The stratigraphy depicted in these sections indicates the influence of the then prevailing opinion that the rock is of sedimentary origin. In the light of the evidence obtained in recent years, tending to prove its igneous origin, these sections would now, doubtless, be considerably modified.

The object of these notes is to describe certain rock specimens and minerals collected during the past year and to discuss their characters and the conditions under which they were found to occur, together with any stratigraphic significance that may attach to them.

I am indebted to Dr. Charles P. Berkey for the preparation of their sections for microscopic examination and to Dr. A. A. Julien for their critical study, the results of which will be given in the next communication of this evening.

The rock is everywhere extensively fractured and is traversed by what is apparently a uniform system of jointing, which coincides in general with the trend and slope of the hills and simulates more or less closely the features of strike and dip in sedimentary rocks. Deductions based upon these features alone would justify the opinion that the rock might represent a metamorphosed series of sediments and the area are inclined anticline, with a dip approximating 90 degrees in places along the eastern and southern escarpment and 45 degrees or less throughout the northwestern slope.

The system of jointing is best defined in the vicinity of Richmond, where the rock is denser, less weathered and more uniform in texture than it is at the northeastern end of the hills. In the latter region the major system of jointing is almost obliterated by innumerable fractures and shear planes and evidences of squeezing, slipping and shearing. It is here also that there is the greatest variation in the rock and the greatest number and variety of minerals.

Where the rock is weathered it is soft and yellowish in color. It contains considerable iron, in the form of magnetite and chromite, which, in the process of weathering, become oxidised into limonite. The soft yellow phase of the rock, accompanied by local deposits of limonite, is best seen at the northeastern end of the hills, where the glaciation was limited, and over the unglaciated area on Todt Hill. At the southwestern end, where glaciation was more pronounced, the upper, weathered zone was eroded, and the rock is hard and dense in texture and dark green in color.

Probably the finest series of rock specimens and characteristic minerals

---

[1] COZZENS, ISSACHAR. "A Geological History of Manhattan or New York Island, etc." Plate 4, "Section of Staten Island from the Telegraph to the Kills." 1843.

BRITTON N. L. "On the Geology of Richmond County, N. Y." Annals New York Acad. Sci., Vol. II, Plate 16, section C. D. 1882.

ever obtained from the Staten Island serpentine were recently collected during the progress of excavating a trench for the first section of the retaining wall along the east side of Jay Street, near the ferry landing at St. George. A projecting spur of the eastern edge of the serpentine escarpment was cut away for a distance of some seventy-five feet, almost down to tide level, exposing a vertical face twenty feet in height and affording a view of the rock at a lower level than had been anywhere previously visible on the Island. It consisted largely of hornblende and amphibolite or anthophyllite schist, with seams of talc and chlorite, arranged in a sharply inclined or vertical series, with a general northeast-southwest trend. The so-called serpentine rock associated with these was very dark green in color, hard and much sheared and fractured, the fractures often containing veins of talc, marmolite, calcite, arrogonite and magnesite. The anthophyllite schist is apparently identical with rock struck at a depth of 200 feet in a well boring at Bischoff's brewery, on the edge of the escarpment about two miles to the southwest, in Stapleton.

The great variation in the character of the rock from place to place might seem to preclude the probability that it was all derived from one source; but numerous field observations and determinations of the mineral constituents by microscopic examination indicate conclusively, that all had a common origin and that this was a basic igneous rock such as an enstatite or a pyroxenite.

The fact that the most extensive fracturing and shearing occurs along the face of the steep eastern escarpment is significant and at once suggests a fault as the probable cause of the escarpment. Slickensided surfaces on the eastern flanks of Pavillion Hill and Gryme's Hill also strongly support this idea.

Any suggestions in relation to the manner in which the serpentine should be indicated, in depicting a geologic section across Staten Island, would be welcomed.

Dr. **Julien** reviewed the petrographic variation of Staten Island serpentines and pointed out the evidence favorable to the theory that only enstatiet and pyroxenite rocks were the originals from which all came. Secondary products are believed to indicate three subsidences and three elevations, or re-elevations, into the zone of weathering. A diagram showing these stages was exhibited and explained. A specimen of bowenite, possibly one of the best ever found anywhere, was shown, on which there are still preserved traces of the crystal outlines of original diopside.

Much discussion was aroused by these papers over the relation of the serpentines to other formations and the probable structures involved. Remarks were made by Professor Kemp, Dr. Levison and Dr. Berkey, and replies by Dr. Hollick and Dr. Julien.

Mr. **Fohs** gave a comprehensive description of fluorspar occurrences in Kentucky and explained the evidence bearing upon their origin. The paper was based on extensive personal knowledge of the subject and was very instructive.

The Section then adjourned.

CHARLES P. BERKEY,
Secretary.

ADJOURNED BUSINESS MEETING.

NOVEMBER 8, 1909.

The Academy met at 8:15 P. M. at the American Museum of Natural History, Vice-President Chapman presiding in the absence of President Cox.

The minutes of the meetings of October 4 and November 1 were read and approved.

The following candidates for Membership, recommended by the Council, were duly elected:

Active Membership:

T. Quincy Brown,	Morristown, N. J.,
George H. Girty,	Washington, D. C.,
E. J. Thatcher, Jr.,	Teachers' College,
J. Edmund Woodman,	New York University.

Associate Active Membership:

Clarence N. Fenner,	Paterson, N. J.,
Julius M. Johnson,	101 West 130th Street,
Victor Ziegler,	Columbia University.

On motion the matter of memorials of Messrs. Newcomb, Johnson and Reade, whose deaths were reported at the October meeting of the Academy, were referred to the Committee on Resolutions for action.

The Recording Secretary reported the death of John H. Caswell, an Active Member of the Academy since 1869, and referred briefly to Mr. Caswell's early activity in the Academy and his long and valuable services as a member of the Finance Committee.

The Academy then adjourned.

EDMUND OTIS HOVEY,
Recording Secretary.

SECTION OF BIOLOGY.

NOVEMBER 8, 1909.

Section met at 8:20 P. M., Vice-President Chapman presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Charles H. Townsend, A NATURALIST IN THE STRAITS OF MAGELLAN.
Alexander Petrunkevitch, A TRIP THROUGH TROPICAL MEXICO.

The following nominations were made for sectional officers for 1910:

For Chairman (and Vice-President of the Academy):

Prof. Chas. B. Davenport, Director of the Carnegie Station for Experimental Evolution, Cold Spring Harbor, L. I.

For Secretary:

Dr. L. Hussakof, American Museum of Natural History.

SUMMARY OF PAPERS.

Dr. **Townsend** gave an account of personal experiences in the Straits of Magellan while a member of a scientific expedition to that region several years ago. He spoke at length of the more interesting mammals, birds, fishes and plants seen or collected. The paper also dealt with the habits of the native tribes of that region. Those living along the more westerly channels of the straits go almost naked, subsist mainly on shell-fish and, in the speaker's opinion, are the lowest among primitive races of man. They are fast disappearing and should be carefully studied.

The paper was illustrated by lantern slides mostly from photographs by the author.

Dr. **Petrunkevitch** spent two months during the summer of 1909 in the lowlands of tropical Mexico collecting arachnida and other invertebrates for the American Museum of Natural History. The paper dealt with his experiences in the field. Many interesting forms were observed and collected, some of which the speaker exhibited.

The Section then adjourned.

L. HUSSAKOF,
Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

NOVEMBER 15, 1909.

Section met at 8:15 P. M., Vice-President Hering presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

J. P. Simmons, LUBRICATION AND LUBRICANTS.

SUMMARY OF PAPER.

Mr. **Simmons** said: The object of all mechanisms is to control the utilization of energy for the performance of useful work. Owing to imperfections in machinery, however, a large percentage of the energy applied is wasted mainly in overcoming the resistance to relative motion offered by moving parts. The least force applied to a perfect machine should set it in motion, and owing to the inertia of its parts, it should maintain a motion of uniform velocity, provided it performed no work. However, certain factors tend to prevent this, and these are first, the friction of the air, and second, the friction due to the rubbing surfaces. The former may be reduced to a minimum by the proper shaping of the moving parts and the second by the use of suitable lubricants. Before considering practical lubrication it might be well to inquire into the nature of solid friction or the friction which results when the surfaces of solid bodies move upon one another without the application of a lubricant.

If two clean surfaces be pressed together considerable work has to be done in order that they shall move relatively to one another. Now this resistance which requires the expenditure of work is what we call solid friction, and of course this will be much less between hard and polished surfaces than between soft and rough.

Illustration: Walking on ice and sandstone. Now this so-called solid friction is due largely to unevennesses of the moving surfaces. Absolutely smooth surfaces cannot be produced.

Cohesion is another factor which requires consideration in this connection. This is aggravated rather than diminished by efforts to produce smooth surfaces.

The lubricating value of an oil depends largely upon its viscosity or the resistance it offers to a shearing stress. If we consider two surfaces xx and yy, supposing yy to be stationary and xx to move with a uniform velocity,

and the two to be separated by a layer of oil; then the layer of lubricant next to xx moves along with it, while that next to yy remains stationary. The intermediate layers of lubricant may be considered as moving one upon another, and the resistance offered to this motion is caused by the viscosity or internal friction of the lubricant considered. It is obvious then that the measurement of the viscosity of oils and the way in which this property is influenced by certain conditions should be an important consideration when it comes to a question of the suitableness of an oil for any particular purpose. It might be mentioned at this point, also, that although viscosity is an essential characteristic of liquid lubricants, the presence of this property alone does not qualify a substance for lubricating purposes. Molasses for example is very viscous, but lacks the so-called "body" or "oiliness" which would enable it to insinuate itself between two surfaces and maintain there, a sufficient thickness of material to prevent actual contract of the moving parts. Various methods have been suggested for the measurement of the liquid friction or viscosity of a lubricant, the most practical of which consists in noting the time it takes for a given quantity to flow through a small opening at a constant temperature. In Germany the Engler, in England the Redwood, and in the United States the Saybolt are the chief forms used.

In practical work the determination of the gravity and the viscosity, as a rule, furnishes sufficient check upon the raw materials and the finished products. It is, however, very often necessary and important that other physical tests be applied. To prevent the use of oils which might, when heated, give off inflammable gases the determination of the "flash point" and "fire point" becomes essential.

Some lubricants, too, are used at very low temperature, for instance, in the operation of an ammonia compressor, and here it is important that the lubricant should not solidify by the action of the cold, for under these conditions the energy needed to operate the machine would be very materially increased.

We have then these six physical tests, (1) Gravity, (2) Flash, (3) Fire, (4) Chill, (5) Cold, (6) Viscosity, which are usually sufficient to O. K. or condemn a lubricant.

If in dealing with lubricating materials, we only had to consider petroleum products the above tests would be all that would be required. Many of the lubricants on the market to-day, however, contain varying small percentages of the so-called "fixed oils" which are either of plant or animal origin and whose detection and estimation, though important, involves purely chemical process and cannot be taken up at this time.

The Section then adjourned.

William Campbell,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

NOVEMBER 22, 1909.

Section met in conjunction with the New York Branch of the American Psychological Association at 8:15 P. M., Prof. J. McK. Cattell presiding in the absence of the chairman.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

Edward L. Thorndike, SOME NEW DATA ON FATIGUE.

A. J. Rosanoff and **Miss G. H. Kent**, A PRELIMINARY REPORT OF A STATISTICAL STUDY OF ASSOCIATION.

R. S. Woodworth, AN ATTEMPT TO STANDARDIZE CERTAIN TESTS OF CONTROLLED ASSOCIATION.

F. Lyman Wells, THE MEANING OF THE ASSOCIATION TEST.

SUMMARY OF PAPERS.

Professor **Thorndike** reported on sixteen subjects worked from 300 to 700 minutes with no rest or only a short rest for luncheon. The work was the mental multiplication of three-place by three-place numbers. Each subject was tested again after a rest of 12 hours or more. The loss in efficiency was not great, being more than counterbalanced by the practise effect and was not closely correlated with subjective estimates of fatigue.

Dr. **Rosanoff** and Miss **Kent**, with the object in view of deriving a normal standard of association to be used in a study of disturbance of flow of thought in insanity, applied Sommer's association test, in a form modified by them, to one thousand normal persons. In their attempts to analyze and classify the results, they found it necessary to depart from the methods of grouping reactions which had been generally in vogue, but found that for their purposes the most useful distinction was that between common and individual reactions. With but few exceptions, records from normal persons contain not over ten per cent. of individual reactions. In cases of insanity, over fifty per cent. of individual reactions were frequently obtained. The distinction between a common and an individual reaction can be readily made by reference to the tables compiled by the authors on the basis of the thousand normal records already referred to. The authors believe that the diagnosis

of incipient insanity in backward school pupils or in eccentric persons will be aided by the use of their tables and that possibly the study of normal mental development may also be aided. The results of the work on association in normal persons are being prepare for publication.

Professor **Woodworth** said, in abstract: This work was undertaken with the coöperation of Dr. F. Lyman Wells, under a committee of the American Psychological Association. The object has been to make a careful selection of the material available for tests of controlled association where the measurement is to be in terms of time. Some of the tests selected, and others in process of selection, were presented.

Dr. **Wells** presented a study of the time relations in the word list of Dr. Rosanoff and Miss Kent. The reason why free association time is longer than controlled association time is not an intellectual but a volitional one. The task of deciding on a suitable response is much greater in free than in controlled associations and through this the longer times of the former are essentially due. This difficulty of decision may be described as the product of striving for a response that will seem sufficiently dignified, or for one that shall not betray something which it is desired to hide, or as a product of distraction induced by special interest possessed by the stimulus word. Those individuals who decide on their responses promptly have short times and closely packed distributions; long times and variable distributions are seen in those who fumble with the experiment, and hesitate about which is the best response to give. In respect to this variability the fifteen women subjects fell into two species, eight being below and seven above the central tendency of the ten men subjects. The median times of the individual words in the last range from 7 to 20 fifths of a second. Out of the 2500 associations, 90 were 10 seconds and over in length, the women giving proportionately three times of those as the men. The rôle of special "complexes' in these reactions was probably a very subordinate one. What is measured by the free association time in the conventional psychological test is, in effect, the ability of the individual to make prompt choices and decisions under the experimental conditions imposed. The sex differences here observed are probably secondary to the special conditions of the experiment.

The Section then adjourned.

R. S. Woodworth,
Secretary.

BUSINESS MEETING.

DECEMBER 6, 1909.

The Academy met at 8:15 P. M. at the American Museum of Natural History, President Cox presiding.

The minutes of the meeting of November 8 were read and approved.

The following candidates for Associate Active Membership, recommended by the Council, were duly elected:

Miss Elvira Wood,	Columbia University,
Frederick K. Morris,	485 Central Park West,
Paul Billingsley,	446 Macon St., Brooklyn,
Joseph P. Byrne,	1133 Broadway.

The Recording Secretary reported the following death:

Dr. Kakichi Mitsukuri, an Honorary Member since 1908.

The Recording Secretary then brought forward the amendment to Chapter 5, Paragraph 1, of the By-Laws, making the third sentence of that paragraph read "Failure to pay the required dues within three months after notification of election has been sent shall render the election void," this amendment having been proposed in due form at the October meeting. On motion, the amendment was unanimously adopted.

The Recording Secretary then offered in writing from Dr. N. L. Britton the following amendment to the Constitution: "Change the fourth sentence of Article II so that it shall read 'Corresponding and Honorary Members shall be chosen from among persons who have attained distinction in some branch of science.'" According to the constitution, this amendment is to be voted upon at a succeeding ordinary business meeting of the Academy after notice has been given in due form by the Recording Secretary.

Prof. James F. Kemp then presented orally a brief but sympathetic notice of the life and work of Mr. John H. Caswell, an Active Member of the Academy for forty years, whose death was reported at the November meeting. On motion, Professor Kemp was requested to submit his memorial in form for printing.

Professor Kemp called attention to the portraits of Darwin now mounted on the walls of the Academy room.

The Academy then adjourned

EDMUND OTIS HOVEY,
Recording Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

December 6, 1909.

Section met at 8:25 p. m., Vice-President Stevenson presiding.
The minutes of the last meeting of the Section were read and approved.
The following programme was then offered:

C. N. Fenner, Application of the Law of Mass Action to Phenomena of Resorption in Igneous Rocks.

J. J. Stevenson, The Coal Basin of Commentry in Central France.

George H. Girty, The Guadalupian Fauna and New Stratigraphic Evidence.

Summary of Papers.

Mr. **Fenner's** paper was intended to show how the law of mass-action operates to produce irregularities in the crystallization of a magma. If a magma were simply a fusion-solution of certain mineral compounds, which were unable to change their relative proportions by inter-reaction under changing conditions, then crystallization upon cooling would follow the well-known laws of entectiferous solutions with almost absolute exactness. On the contrary, however, we know from the principle of mass-action that the state of chemical equilibrium in a complex solution is in an unstable condition and is easily displaced by various influences, among which temperature and concentration are chief factors.

It follows, therefore, that the removal by crystallization of one or more compounds from a solution affects the relative concentration of the residual material and causes reactions to proceed further in one direction or another. The equilibrium may be so far displaced from the condition at which it stood when crystallization began that in the later stages the crystals first deposited may be attacked and resorbed.

The removal of material by gaseous emanations upon the extrusion of a magma acts in a very similar manner to affect the equilibrium.

Change of temperature is also an important factor, for this alone will cause a change in the conditions of equilibrium within a solution; and a mineral which has crystallized from a magma under great pressure at a temperature slightly higher than the normal may be resorbed when the temperature of crystallization is depressed by relief of pressure, conditions of chemical equilibrium having meanwhile shifted.

In general the two factors, change of temperature and change of concentration, will act simultaneously to effect the irregularities considered.

The paper by Professor **Stevenson** has been published as pages 161–204 of this volume.

The paper by Dr. **Girty** has been published as pages 135–147 of this volume.

The Section then adjourned.

Charles P. Berkey,
Secretary.

SECTION OF BIOLOGY.

December 13, 1909.

Section met at 8:15 p. m., Vice-President Chapman presiding.

The minutes of the last meeting of the Section were read and approved.

The following programme was then offered:

C. William Beebe, Notes of an Ornithologist in South America.

A. J. Goldfarb, The Influence of the Nervous System in Regeneration.

Summary of Papers.

Mr. **Beebe** gave an account of three expeditions to the forest regions of British Guiana, South America, for the purpose of studying and collecting the rarer birds of that locality. Many admirable photographs were shown of rare birds, among them the first photographs ever taken of the hoctyui, the female being shown in her characteristic crouching attitude near the nest and a flock of eleven in one tree. Incidentally some remarkable photographs of mammals were obtained, among them one showing six capybaras and several young on a river bank taken by Dr. Hiram Bingham and one of a manatee swimming with mouth and nostrils just above the water.

Mr. **Goldfarb** briefly reviewed the suggestions that had heretofore been made to account for the fact that some animals were able to replace a missing organ, while others were unable to do so. A concise summary was then given of the experimental data that supported the conclusion that regeneration was dependent upon a stimulus exerted by or through the central nervous system.

The speaker then described the experiments that he had made during the last several years upon five widely different kinds of animals. In each animal the most painstaking care was taken to make certain that all motor or sensory or both of these cells, innervating a given organ, had been completely destroyed. In spite of the total removal of the nerve stimuli the missing organ was regenerated in every case. Thus the frog tadpole regenerated its tail, the adult newt, *Diemyctylus viridescens*, regenerated its tail and leg, the earthworm its head, the starfish its arm, and the planarian, *Dendrocœlum lacteum*, the anterior third of its body. It was pointed out that the agreement among these very different organisms probably signified that animals as a whole, whether during their larval or during their adult stage of development, regenerate their missing organs independently of a central nerve stimulus.

The Section then adjourned.

L. Hussakof,
Secretary.

ANNUAL MEETING.

December 20, 1909.

The Academy met for the Annual Meeting on Monday, December 20, 1909, at 6:45 P. M. at the Hotel Endicott, President Cox in the chair.

The minutes of the last Annual Meeting, December 21, 1908, were read and approved.

Reports were presented by the Recording Secretary, the Corresponding Secretary, the Librarian and the Editor, all of which, on motion, were ordered received and placed on file. They are published herewith.

The Treasurer presented a detailed report showing a net cash balance of $1,737.69 on hand at the close of business November 30, 1909. On motion, this report was received and referred to the Finance Committee for auditing.

The following candidates for Honorary Membership and Fellowship, recommended by Council, were duly elected:

Honorary Members.

Geh. Rat Prof. Dr. K. F. Goebel, Botanist, University of Munich, Germany,

Geh. Rat Prof. Dr. Paul von Groth, Mineralogist, University of Munich, Germany,

Prof. ALFRED LACROIX, Mineralogist and Geologist, Musée d'Histoire Naturelle, Paris, France,

Excellency Geh. Rat Prof. Dr. AUGUST WEISMANN, Zoölogist, University of Freiburg, Germany.

Fellows.

ROY C. ANDREWS, American Museum of Natural History,
WM. M. CAMPBELL, New York University,
GEORGE H. GIRTY, U. S. Geological Survey, Washington, D. C.,
LOUIS HUSSAKOF, American Museum of Natural History,
HENRY S. PRITCHETT, Carnegie Foundation,
J. EDMUND WOODMAN, New York University.

The Academy then proceeded to the election of officers for the year 1910, Messrs. Christian F. Groth and Charles L. Pollard having been appointed as tellers. The ballots prepared by the Council according to the By-Laws were distributed, and after the votes had been counted the following officers were declared unanimously elected, more than 25 votes having been cast by members of the Academy entitled to vote:

President, JAMES F. KEMP.

Vice-Presidents, GEORGE F. KUNZ (Section of Geology and Mineralogy), CHAS. B. DAVENPORT (Section of Biology), WILLIAM CAMPBELL (Section of Astronomy, Physics and Chemistry), MAURICE FISHBERG (Section of Anthropology and Psychology).

Recording Secretary, EDMUND OTIS HOVEY.

Corresponding Secretary, HERMON CAREY BUMPUS.

Treasurer, EMERSON MCMILLIN.

Librarian, RALPH W. TOWER.

Editor, EDMUND OTIS HOVEY.

Councilors (to serve 3 years), BASHFORD DEAN, J. E. WOODMAN.

Finance Committee, CHARLES F. COX, GEORGE F. KUNZ, FREDERIC S. LEE.

The members of the Academy and their friends, to the number of fifty-eight, then sat down together at dinner, after which the retiring President, Mr. Charles F. Cox, delivered his formal address upon "The Founder of the Evolution Theory." This address has been published as pages 225–245 of this volume.

After a vote of thanks, which was put with apt remarks by former President J. J. Stevenson, the Academy adjourned.

EDMUND OTIS HOVEY,
Recording Secretary.

REPORT OF THE RECORDING SECRETARY.

During the year 1909, the Academy held 8 business meetings and 25 sectional meetings, at which 148 stated papers were presented on the following subjects:

Geology,	15
Mineralogy,	5
Biology,	20
Entomology,	39
Ornithology,	10
Paleontology,	2
Zoölogy,	2
Botany,	22
Archæology and Anthropology,	8
Psychology,	10
Physics,	10
Chemistry,	6

Five public lectures have been given at the Museum to the members of the Academy and the Affiliated Societies and their friends. These lectures were as follows:

"Mimicry Among North American Butterflies." By Professor Edward B. Poulton of the University of Oxford, England, Corresponding Member of the Academy. (Through coöperation with the Brooklyn Entomological Society).

"The Wonders of Alaska." By Mr. Alfred H. Dunham of Nome. (Through coöperation with the Linnæan Society of New York.)

"The Antiquity of Man." By Prof. Dr. Albrecht Penck of Berlin, Germany, Honorary Member of the Academy.

"Austria and Its Beauties." By Mr. Felix Leibinger of Vienna, Austria. (Through coöperation with the Austrian Society.)

"Common Mushrooms and How to Know Them." By Miss Nina L. Marshall of Metuchen, N. J.

At the present time the membership of the Academy includes 437 Active Members, 15 of whom are Associate Active Members, 127 Fellows, 67 Life Members and 13 Patrons. The election of 6 Fellows is pending. There have been 8 deaths during the year, 20 resignations have become effective and 1 name has been transferred to the list of Non-Resident Members. The new members elected during the year number 16, 1 of whom has not

yet completed his membership. As the membership of the Academy a year ago was 458, there has been a net loss of 24 during the year 1909.

Announcement is made with regret of the loss by death of the following members:

W. A. Anthony,	Active Member (4 years),
Miss Matilda Bruce,	Patron (2 years),
John H. Caswell,	Active Member (40 years),
E. H. Harriman,	Active Member (5 years),
John S. Kennedy,	Active Member (12 years),
T. W. Pearsall,	Active Member (2 years),
H. H. Rogers,	Active Member (12 years),
W. Wheeler Smith,	Active Member (3 years),
Alfred R. Wolff,	Active Member (11 years).

Respectfully submitted,

Edmund Otis Hovey,
Recording Secretary.

REPORT OF THE CORRESPONDING SECRETARY.

We have lost by death during the past year the following Honorary Members:

Professor Wolcott Gibbs,	Elected in 1890,
Dr. Kakichi Mitsukuri,	Elected in 1908,
Simon Newcomb,	Elected in 1891,

and the following Corresponding Members:

Professor Samuel W. Johnson,	Elected in 1876,
T. Mellard Reade,	Elected in 1888.

There are at present upon our rolls 46 Honorary Members and 140 Corresponding Members.

Respectfully submitted,

Hermon Carey Bumpus,
Corresponding Secretary.

REPORT OF THE LIBRARIAN.

The library of the New York Academy of Sciences has received during the year 1909, through exchange and donation, 309 volumes, 48 separata and 1502 numbers. Special acknowledgments are herewith made to those institutions which have made gifts of available lacunæ in our files of their publications,— especially to the Deutscher Naturwissenschaftlichmedizinischer Verein für Böhmen "Lotos" in Prag for a complete set of their publications since 1853 to date, and also for 9 volumes of the "Abhandlungen der k. Akademie der Wissenschaft in Berlin" dating from 1816 to 1826.

A complete list of the exchanges of the Academy is submitted herewith.[1]

Respectfully submitted,

RALPH W. TOWER,
Librarian.

REPORT OF THE EDITOR.

The Editor reports that during the past fiscal year Part III, completing Volume XVIII, was distributed, and that Numbers 1 to 5 inclusive of Part I of Volume XIX have been printed. Part III of Volume XVIII contained the following papers:

"An Investigation of the Figure of the Sun and of Possible Variations in its Size and Shape." By Charles Lane Poor.

"Outline of the Geology of Long Island, N. Y." By W. O. Crosby.

"Charles Darwin and the Mutation Theory." By Charles F. Cox.

"Records of Meetings, 1908." By Edmund Otis Hovey.

The numbers of Part I of Volume XIX that have already been distributed are the following:

"Darwin Memorial Celebration." By Edmund Otis Hovey.

"Plan and Scope." Correlation Bulletin No. 1. By Henry F. Osborn and W. D. Matthew.

"Studies on the Morphology and Development of Certain Rugose Corals." By Thomas Clacher Brown.

"The Fossil Vertebrates of Belgium," By Louis Dollo. Correlation Bulletin No. 2. Translated by W. D. Matthew.

"On the Origin and Sequences of the Minerals of the Newark (Triassic) Igneous Rocks of New Jersey." By Wallace Goold Levison.

[1] See page 335.

The Annual Directory of the Members of the Academy and its Affiliated Societies was issued as of 1 January, 1909.

We now have in press the following papers:

"Patagonia and the Pampas Cenozoic of South America. A Critical Review of the Correlations of Santiago Roth, 1908." Correlation Bulletin No. 3. By W. D. Matthew.

"Guadalupian Fauna and New Stratigraphic Evidence." By George H. Girty.

We have in manuscript the following papers:

"The Commentry Coal Basin of Central France." By J. J. Stevenson.

"Some New or Little Known American Spiders." By Alexander Petrunkevitch.

Respectfully submitted,

Edmund Otis Hovey,
Editor.

REPORT OF THE TREASURER.

RECEIPTS.

December 1, 1908,–November 30, 1909.

Balance on hand, November 30, 1908		$193.56
Income from investments:		
Interest on mortgages on New York City real estate	$886.00	
Interest on railroad and other bonds	1,070.00	
Interest on bank balances	44.34	$2,000.34
Life Membership fees		300.00
Active Membership dues, 1906	30.00	
" " " 1907	70.00	
" " " 1908	135.00	
" " " 1909	2,963.00	3,198.00
Associate Membership dues, 1907	3.00	
" " " 1908	3.00	
" " " 1909	39.00	45.00
Headquarters Committee, Return of balance of appropriation		40.00
Sales of publications		97.38
Subscriptions to Darwin Celebration		972.00
" " Annual Dinner		158.00
Esther Herrman Research Fund, Return of appropriation		318.00
Total		$7,322.28

DISBURSEMENTS.

December 1, 1908,— November 30, 1909.

Interest on debit balance in bank	$1.86
Publications, on account of Annals	1,175.05
Recording Secretary's office expenses, including publication of *Bulletin*	925.88
Recording Secretary's and Editor's allowance	1,200.00
Darwin celebration	1,125.10
Lecture Committee	100.00
General expenses	114.00
Esther Herrman Research Fund	450.00
John Strong Newberry Fund	100.00
Headquarters Committee	246.20
Annual meeting and dinner	146.50
Cash on hand	1,737.69
Total	$7,322.28

BALANCE SHEET, NOVEMBER 30, 1909.

Investments	$36,602.50	Permanent Fund	$18,102.75
Cash on hand	1,737.69	Publication Fund	3,000.00
		Audubon Fund	2,360.95
		Building Fund	10,400.00
		Newberry Fund	1,046.25
		Income of Permanent Fund	1,591.57
		Income of Audubon Fund	75.00
		Income of Building Fund	876.96
		Income of Newberry Fund	239.01
		General Income	647.70
	$38,340.19		$38,340.19

Examined and approved,

GEORGE F. KUNZ,
FREDERIC S. LEE, } *for the Auditing Committee.*

LIST OF THE SOCIETIES AND OTHER ORGANIZATIONS WITH WHICH THE ACADEMY EXCHANGES PUBLICATIONS.

December, 1909.

Argentine Republic.

Museo Nacional de Buenos Aires, Buenos Aires.
Academia Nacional de Ciencias, Cordoba.
Museo de La Plata, La Plata.

Australia.

Royal Geographical Society of Australia, Brisbane, Queensland.
Royal Society of Queensland, Brisbane, Queensland.
Department of Mines and Water Supply, Melbourne, Victoria.
Australian Society for the Advancement of Science, Sydney, New South Wales.
Australian Museum, Sydney, New South Wales.
Department of Mines, Sydney, New South Wales.
Geological Survey of New South Wales, Sydney, New South Wales.
Linnæan Society of New South Wales, Sydney, New South Wales.
Royal Society of New South Wales, Sydney, New South Wales.
Royal Society of South Australia, Adelaide, South Australia.
Geological Survey Office, Perth, Western Australia.

Austria-Hungary.

(a) Austria.

Naturforschender Verein in Brunn, Brünn.
Kaiserliche Akademie des Wissenschaften, Krakau.
Ševčenko-Gesellschaft der Wissenschaften, Lemberg.
Comité fur Naturwissenschaftliche Landesdurchforschung von Bohmen. Prag.
Deutscher naturwissenschaftlich-medizinischer Verein fur Bohmen "Lotos," Prag.
Konigliche Bohmische Gesellschaft der Wissenschaften, Prag.
Naturwissenschaftlicher Verein, an der Universität Wien, Wien.
Kaiserliche Akademie der Wissenschaften, Wien.

(b) Hungary.

Journal der Naturgeschichte (Ungarisches National-Museum), Buda-Pest.
Ungarische Akademie der Wissenschaften, Buda-Pest.
Königliche Ungarische geologische Anstalt, Buda-Pest.
Königliche Ungarische Gesellschaft für Naturwissenschaften, Buda-Pest.
Siebenbürgisches National-Museum, Klausenburg.
Ungarischer Karpathenverein, Löcse.
Konigliches Kroatisches Landesarchiv, Zagreb.

Belgium.

Académie Royale des Sciences, des Lettres et des Beaux-Arts à Bruxelles, Bruxelles
Observatoire Royale de Bruxelles, Bruxelles.
Bibliothéque de la Société Belge de Géologie, Bruxelles.
Société Entomologique de Belgïque, Bruxelles.
Société Royale de Botanique, Bruxelles.
Société Géologique de Belgique, Liège.
Société Royale des Sciences de Liège, Liège.

Brazil.

Museu Goeldi de Historia Natural e Ethnographia, Pará.
Museu Nacional do Rio de Janeiro, Rio de Janeiro.
Jardim Botanico, Rio de Janeiro.
Observatorio do Rio de Janeiro, Rio de Janeiro.
Museu Paulista, São Paulo.

Canada.

Nova Scotian Institute of Sciences, Halifax, Nova Scotia.
Hamilton Scientific Association, Hamilton, Ontario.
Geological Survey of Canada, Ottawa.
Ottawa Field Naturalists' Club, Ottawa.
Royal Society of Canada, Ottawa.
Natural History Society of New Brunswick, St. John, New Brunswick.
Canadian Institute, Toronto.
Royal Astronomical Society of Canada, Toronto.
University of Toronto Library, Toronto.

Chili.

Société Scientifique du Chili, Santiago.

Costa Rica.

Museo Nacional de Costa Rica, San José.

Cuba.

Anales de la Academia de Ciencias Medicas, Fisicas y Naturales de la Habana, Habana.

Denmark.

Kongelige danske Videnskabernes Selskab i Kjöbenhavn, Kjöbenhavn.
Naturhistorisk Forening, Kjöbenhavn.

France.

Société d'Études Scientifiques d'Angers, Angers.
Société des Sciences Historiques et Naturelles de l'Yonne, Auxerre.
Société Medicale de l'Yonne, Auxerre.
Société Linnéenne de Bordeaux, Bordeaux.
Société des Sciences Physiques et Naturelles de Bordeaux, Bordeaux.
Académie Nationale des Sciences, des Arts et des Belles Lettres de Caen, Caen.
Laboratoire de Géologie de la Faculté des Sciences, Caen.
Société Linnéenne de Normandie, Caen.
Société Nationale des Sciences, Cherbourg.
Société de Borda, Dax.
Académie des Sciences, des Arts et des Belles-Lettres de Dijon, Dijon.
Union Géographique du Nord de la France, Douai.
Société Géologique du Nord, Lille.
Bibliothéque de la Université de Lyon, Lyon.
Société Botanique de Lyon, Lyon.
Société d'Agriculture, Sciences et Industrie, Lyon.
Académie des Sciences et Lettres de Montpellier, Montpellier.
Académie de Stanislas, Nancy.
Société des Sciences de Nancy, Nancy.
Observatoire Metéorologique du Mont Blanc, Nice.
Académie de Médécine, Paris.
Académie des Sciences de l'Institut de France, Paris.
École Polytechnique, Paris.
École Nationale des Mines, Paris.
Muséum d'Histoire Naturelle, Paris.
Société Entomologique de France, Paris.
Société Géologique de France, Paris
Société Nationale d'Agriculture de France, Paris.
Société Zoologique de France, Paris.
Société des Amis des Sciences Naturelles de Rouen, Rouen.
Société de l' Industrie Minerale, Ste. Etienne.
Académie des Sciences, des Inscriptions et des Belles-Lettres de Toulouse, Toulouse.
Société d'Histoire Naturelle de Toulouse, Toulouse.
Laboratoire de Zoologie, Villefranche-sur-Mer.

Germany.

Naturforschende Gesellschaft des Osterlandes zu Altenburg, Altenburg.
Naturhistorischer Verein für Schwaben und Neuberg, Augsburg.
Naturforschende Gesellschaft, Bamberg.
Berliner entomologischer Verein, Berlin.
Centralbureau der internationalen Erdmessung, Berlin.
Botanischer Verein der Provinz Brandenburg, Berlin.
Deutsche geologische Gesellschaft, Berlin.
Deutsche Gesellschaft für öffentliche Gesundheitspflege, Berlin.
Gesellschaft für Erdkunde, Berlin.

Gesellschaft Naturforschender Freunde, Berlin.
Königliche Preussische Akademie der Wissenschaften zu Berlin, Berlin.
Königliche Preussische geologische Land-Berg Akademie, Berlin.
Königliches Preussisches meteorologisches Institut, Berlin.
Physikalische Gesellschaft, Berlin.
Verein zur Beförderung des Gartenbaues in den Preussischen Staaten, Berlin.
Naturhistorischer Verein der Preussischen Rheinlände und Westphalens, Bonn.
Verein für Naturwissenschaften, Braunschweig.
Naturwissenschaftlicher Verein zu Bremen, Bremen.
Schlesische Gesellschaft für Vaterländische Cultur, Breslau.
Naturwissenschaftliche Gesellschaft, Chemnitz.
Technische Staats-Lehr-Anstalt, Chemnitz.
Naturforschende Gesellschaft in Danzig, Danzig.
Verein für Erdkunde, Darmstadt.
Naturwissenschaftliche Gesellschaft "Isis" in Dresden, Dresden.
Verein für Erdkunde, Dresden.
Naturforschende Gesellschaft, Emden.
Senckenbergische naturforschende Gesellschaft, Frankfurt-am-Main.
Naturwissenschaftlicher Verein, Frankfurt-am-Oder.
Naturforschende Gesellschaft zu Freiburg i. Br., Freiburg i.-Br.
Naturforschende Gesellschaft, Görlitz.
Königliche Gesellschaft der Wissenschaften, Gottingen.
Geographische Gesellschaft, Greifswald.
Naturwissenschaftlicher Verein für Neuvorpommern und Rügen zu Greifswald, Greifswald.
Kaiserliche Leopoldino-Carolinische Deutsche Akademie der Naturforscher, Halle-an-der-Salle.
Naturwissenschaftlicher Verein fur Sachsen und Thuringen, Halle-an-der-Salle.
Geographische Gesellschaft in Hamburg, Hamburg.
Naturhistorisches Museum zu Hamburg, Hamburg.
Naturwissenschaftlicher Verein in Hamburg, Hamburg.
Wetterauische Gesellschaft für die Gesammte Naturkunde, Hanau.
Naturhistorische Gesellschaft in Hannover, Hannover.
Naturhistorisch-medicinischer Verein, Heidelberg.
Königliche biologische Anstalt, Helgoland.
Römer Museum, Hildesheim.
Verein fur Hessische Geschichte und Landeskunde in Kassel, Kassel.
Kommission zur wissenschaftlichen Untersuchung der Deutchen Meere, Kiel.
Naturwissenschaftlicher Verein für Schleswig-Holstein, Kiel.
Königliche physikalisch-okonomische Gesellschaft zu Königsburg, Königsburg.
Deutsche Physikalische Gesellschaft, Leipzig.
Fürstliche Jablonowski'sche Gesellschaft zu Wissenschaften, Leipzig.
Königliche Sachsische Gesellschaft der Wissenschaften zu Leipzig, Leipzig.
Verein fur Erdkunde, Leipzig.
Naturhistorisches Museum, Lübeck.
Naturwissenschaftlicher Verein, Luneberg.
Naturwissenschaftlicher Verein, Magdeburg.
Société d'Histoire Naturelle, Metz.
Verein für Erdkunde zu Metz, Metz.

Königliche Bayerische Akademie der Wissenschaften zu München, Munich.
Königliche Sternwarte Bogenhausen bei München, Munich.
Provinzial Verein für Wissenschaft und Kunst, Münster.
Naturhistorische Gesellschaft zu Nürnberg, Nürnberg.
Verein für Naturkunde, Offenbach.
Naturwissenschaftlicher Verein, Osnabrück.
Königliches Preussische geodetische Institut, Potsdam.
Naturwissenschaftlicher Verein in Regensburg, Regensburg.
Verein der Freunde der Naturgeschichte in Mecklenburg, Rostock.
Verein für Erdkunde, Stettin.
Verein für vaterländische Naturkunde in Württemberg, Stuttgart.
Nassauischer Verein für Naturkunde, Wiesbaden.
Physisch-medicinische Gesellschaft zu Würzburg, Würzburg.

Great Britain and Ireland.

(a) England.

Birmingham Natural History and Microscopical Society, Birmingham.
Bristol Museum of Natural Nistory, Bristol.
Cambridge Philosophical Society, Cambridge.
Royal Cornwall Polytechnical Society, Falmouth.
Yorkshire Geological and Polytechnical Society, Leeds.
Literary and Philosophical Society, Liverpool.
Liverpool Geological Society, Liverpool.
British Association for the Advancement of Science, London.
British Museum (Natural History), London.
Geological Society, London.
Iron and Steel Institute, London.
Linnæan Society, London.
Royal Institute of Great Britain, London.
Royal Microscopical Society, London.
Society of Arts, London.
Royal Society, London.
Zoölogical Society of London, London.
Manchester Literary and Philosophical Society, Manchester.
Manchester Microscopical Society, Manchester.
Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne, Newcastle-upon-Tyne.
North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.
Norfolk and Norwich Naturalists' Society, Norwich.
Radcliff Observatory, Oxford.
Marine Biological Association of the United Kingdom, Plymouth.
Penzance Natural History and Antiquarian Society, Penzance.
Royal Geological Society, Penzance.
Royal Institute of Cornwall, Truro.
Hertfordshire Natural History Society and Field Club, Watford.
Yorkshire Philosophical Society, York.

(b) Scotland.

Geological Society of Glasgow, Glasgow.
Natural History Society of Glasgow, Glasgow.
Philosophical Society of Glasgow, Glasgow.
Edinburgh Botanical Society, Edinburgh.
Edinburgh Geographical Society, Edinburgh.
Meteorological Society of Scotland, Edinburgh.
Royal Physical Society, Edinburgh.
Dumfriesshire and Galloway Natural History and Antiquarian Society, Dumfries.

(c) Ireland.

Belfast Natural History and Philosophical Society, Belfast.
Belfast Naturalists' Field Club, Belfast.
Geological Survey of Ireland, Dublin.
Royal Dublin Society, Dublin.

HOLLAND.

Koninklijke Akademie van Wetenschappen, Amsterdam.
Koninklijk zoologisch Genootschap "Natura Artes Magistra," Amsterdam.
Bibliotheek der Teyler's Stichting (Museum), Haarlem.
Hollandsche Maatschappij van Wetenschappen, Haarlem.
Rijks Universiteit, Leiden.
Department van Kolonien, 'S-Gravenhage.
Koninklijke Bibliotheek, 'S-Gravenhage.
Koninklijk Nederlandsch Meteorologisch Instituut, Utrecht.
Provinciaal Utrechtsch Genootschap van Kunsten en Wetenschappen, Utrecht.

INDIA.

Agricultural Research Institute, Poona.
Geological Survey of India, Calcutta.

ITALY.

Accademia di Scienze, Letteri ed Arti degli Zelanti Acireale, Acireale.
Reggia Accademia Petrarca, Arezzo.
Accademia delle Scienza dell' Instituto di Bologna, Bologna.
Accademia Gioenia di Scienze Naturali in Catania, Catania.
Società degli Spettroscopisti Italiana, Catania.
Reale Instituto di Studi Superiori Practici e di Perfezionamento, Firenze.
Reale Accademia Peloritana, Messina.
Reale Instituto Lombardo di Scienze e Lettere, Milano.
Regio Instituto Technico-Superiore Milano, Milano.
Società Meteorologica Italiana, Moncalieri.
Reale Accademia di Scienze Fisiche e Mathematiche di Napoli, Napoli.
Reale Accademia di Scienze e Lettere e Belle Arti di Palermo, Palermo.

Reale Osservatorio, Palermo.
Accademia Medico Chirurgica, Perugia.
Società Toscana di Scienze Naturali, Pisa.
Regia Scuola Superiore di Agricoltura, Portici.
Reale Accademia dei Lincei, Roma.
Reale Comitato Geologico d'Italia, Roma.
Specula Vaticana, Roma.
Società Italiana per il Progresso delle Scienze, Roma.
Società per gli Studi della Malaria, Roma.
Reale Accademia dei Fisiocritici, Siena.
Museo di Zoologia e di Anatomia Comparata della Regia Università di Torino, Torino.
Osservatorio della Regia Università di Torino, Torino.
Reale Instituto Tecnico "Antonio Zano" in Udine, Udine.
Ateneo Veneto, Venezia.
Regio Instituto Veneto di Scienze, Lettere ed Arti, Venezia.

JAPAN.

Sapporo Natural History Society, Sapporo.
Science College, Imperial University of Japan, Tokio.

JAVA.

Bataviaasch Genootschapp van Kunsten en Wetenschappen, Batavia.
Koninklijke Natuurkundige Vereeniging in Nederlandsch-Indie, Batavia.
Koninklijk Magnetisch en Meteorologisch Observatorium, Batavia.

MEXICO.

Secretaria de Fomento, Colonizacion, Industria y Comercio, Mexico.
Instituto Medico Nacional, Mexico.
Museo Nacional de Mexico, Mexico.
Sociedad Geologica Mexicana, Mexico.
Sociedad Cientifica "Antonio Alzate," Mexico.
Observatorio Astronomico Nacional, Tacubaya.

NEW ZEALAND.

New Zealand Institute, Wellington.
Mines Department, Geological Survey Branch, Wellington.

NORWAY.

Bergens Museum, Bergen.
Norske Gradmaalings Commission, Christiania.
Norges Geologiske Undersøgelse, Christiania.

Norske Meteorologiske Institut, Christiania.
Videnskabst Selskabet, Christiania.
Zoologiske Museum af Kongelige Universitet, Christiania.
Tromsö Museum, Tromsö.
Kongelige Norske Videnskabers Selskab, Trondhjem.

Paraguay.

Annales Cientificos Paraguayos, Puerto Bertoni.

Portugal.

Academia Real das Sciencias de Lisboa, Lisboa.
Commissão do Serviço Geologico, Lisboa.
Sociedade de Geographia de Lisboa, Lisboa.

Roumania.

Université de Jassy, Jassy.

Russia.

Société des Naturalistes de Dorpat, Dorpat.
Université Impériale, Dorpat.
Société Ouralienne d'Amateurs des Sciences naturelles, Ekaterinburg.
Commission Géologique de la Finlande, Helsingfors, Finlande.
Société Scientifique Ukrainienne, Kiev.
Société des Naturalistes attachés a l'Université Imperiale St. Vladimir à Kiev, Kiev.
Société impériale des Naturalistes de Moscou, Moscou.
"Annuaire Géologique et Minéralogique de la Russie," Nowo-Alexandria.
Société des Naturalistes de Riga, Riga.
Académie Impériale des Sciences de St. Pétersbourg, St. Pétersbourg.
Comité géologique de la Russie, St. Pétersbourg.
Jardin Impérial de Botanique, St. Pétersbourg.
Musée Géologique de l'Université, St. Pétersbourg.
Société Entomologique de Russie, St. Pétersbourg.
Société Impériale Minéralogique, St. Pétersbourg.
Société Physico-chimique Russe à l'Université, St. Pétersbourg.

South Africa.

Royal Society of South Africa, Cape Town.
"South African Journal of Science," Cape Town.
Government Geologist, Pietermaritzburg.

Spain.

Real Academia de Ciencias, Exactes, Fisicas y Naturales, Madrid.
Facultad de Ciencias, Universidad de Zaragoza, Zaragoza.

Sweden.

Kongliga Universitet, Lund.
"Entomologiska Tidskrift," Stockholm.
Geologiska Foreningen i Stockholm, Stockholm.
Kongliga Svenska Vetenskaps Akademien, Stockholm.
Upsala Universitet Mineralogisk-Geologisk Institutionen, Upsala.
Kongliga Universitet, Upsala.
Kongliga Vetenskaps-Societeten, Upsala.

Switzerland.

Naturforschende Gesellschaft, Basel.
Naturforschende Gesellschaft in Berne, Berne.
Schweizerische entomologische Gesellschaft, Naturhistorisches Museum, Berne.
Société Géologique Suisse, Berne.
Thurgauische naturforschende Gesellschaft, Frauenfeld.
Société Friburgoise des Sciences Naturelles, Fribourg.
Institut National Genévois, Geneva.
Société de Physique et d'Histoire Naturelle de Genéve, Geneva.
Société Vaudoise des Sciences Naturelles, Lausanne.
Société des Sciences Naturelles de Neuchâtel, Neuchâtel.
Naturforschende Gesellschaft, Solothurn.
Naturwissenschaftlicher Verein, St. Gall.
Naturforschende Gesellschaft, Zürich.

United States.

Texas Academy of Science, Austin, Texas.
Johns Hopkins University, Baltimore, Maryland.
University of California, Berkeley, California.
American Academy of Arts and Sciences, Boston, Massachusetts.
Boston Society of Natural History, Boston, Massachusetts.
Public Library, Brooklyn, New York.
Buffalo Society of Natural Sciences, Buffalo, New York.
Harvard College Library, Cambridge, Massachusetts.
Harvard College Observatory, Cambridge, Massachusetts.
Museum of Comparative Zoology at Harvard College, Cambridge, Massachusetts.
Elisha Mitchell Scientific Society, Chapel Hill, North Carolina.
Field Museum of Natural History, Chicago, Illinois.
Chicago Academy of Sciences, Chicago, Illinois.
Cincinnati Society of Natural History, Cincinnati, Ohio.
Library of American Association for the Advancement of Science, Cincinnati, Ohio.
Texas Agricultural Experiment Station, College Station, Texas.
Colorado Scientific Society, Denver, Colorado.
Iowa Academy of Sciences, Des Moines, Iowa.
New York Agricultural Experiment Station, Geneva, New York.

Denison Scientific Society, Denison University, Granville, Ohio.
Indiana Academy of Science, Indianapolis, Indiana.
University of Kansas, Lawrence, Kansas.
Wisconsin Academy of Sciences, Arts and Letters, Madison, Wisconsin.
University of Wisconsin, Madison, Wisconsin.
Staten Island Association of Arts and Sciences, New Brighton, New York.
American Journal of Science, New Haven, Connecticut.
Connecticut Academy of Arts and Sciences, New Haven, Connecticut.
American Geographical Society, New York, New York.
American Institute of Mining Engineers, New York, New York.
American Museum of Natural History, New York, New York.
Columbia University Library, New York, New York.
Torrey Botanical Club, New York, New York.
Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania.
American Philosophical Society, Philadelphia, Pennsylvania.
Engineers' Club of Philadelphia, Philadelphia, Pennsylvania.
Franklin Institute, Philadelphia, Pennsylvania.
Carnegie Museum, Pittsburgh, Pennsylvania.
Portland Society of Natural History, Portland, Maine.
Vassar Brothers Institute, Poughkeepsie, New York.
Rochester Academy of Sciences, Rochester, New York.
Missouri Geological Survey, Rolla, Missouri.
American Antiquarian, Salem, Massachusetts.
Essex Institute, Salem, Massachusetts.
California Academy of Sciences, San Francisco, California.
California State Mining Bureau, San Francisco, California.
Leland Stanford Junior University Library, Stanford University, California.
Hopkins Seaside Laboratory, Stanford University, California.
Academy of Sciences of St. Louis, St. Louis, Missouri.
Missouri Botanical Garden, St. Louis, Missouri.
Syracuse University, Biological Department, Syracuse, New York.
Kansas Academy of Sciences, Topeka, Kansas.
Washburn Laboratory of Natural History, Topeka, Kansas.
State Geological Survey, Trenton, New Jersey.
Geological Survey of Alabama, University, Alabama.
Illinois State Laboratory of Natural History, Urbana, Illinois.
Biological Society of Washington, Washington, D. C.
Congressional Library, Washington, D. C.
Philosophical Society, Washington, D. C.
Smithsonian Institution, Washington, D. C.
United States Coast and Geodetic Survey, Washington, D. C.
United States Commission of Fish and Fisheries, Washington, D. C.
United States Department of Agriculture, Washington, D. C.
United States Geological Survey, Washington, D. C.
United States National Museum, Washington, D. C.
United States Weather Bureau, Washington, D. C.
Wyoming Historical and Geological Society, Wilkes-Barré, Pennsylvania.
American Antiquarian Society, Worcester, Massachusetts.

MEMOIR OF WOLCOTT GIBBS.[1]

By Theodore William Richards.

The death of Wolcott Gibbs takes a commanding figure from the ranks of the veterans of science. Attaining the age of over eighty-six years, he had been for a long time almost the sole survivor among the pioneers of American chemistry. He was one of the founders of the National Academy of Sciences in 1870; and he alone saw his name included among those of living members in 1908.

For over a decade, he had headed in academic seniority the list of the faculties of Harvard University. He served there as Rumford professor for twenty-four years, and in honorable retirement bore the title of Rumford professor emeritus for twenty-one years more. The infirmity due to his increasing years had withdrawn from him the privilege of contributing to the growth of his beloved science; but his interest in the work of others remained keen and enthusiastic until the end had almost come — until pain had driven away all the joy of life.

It has been said that he was one of the pioneers of American chemistry. He was made assistant professor in New York at the age of twenty-six, in 1848. His eager and energetic spirit and his thorough training under the inspiring guidance of Rose, Rammelsberg, Liebig, Laurent, Dumas and Regnault had given him an insight into the possible future of chemistry which forbade his contentedly settling down into the mere routine of teaching. Thus at once he joined the then pitifully small band of Americans who sought to advance the bounds of knowledge.

It is impossible here to present a detailed survey of the greatly varied fields in which his work lay, but a brief sketch will give some idea of the activity of his scientific imagination. His first important research concerned the complex ammonia-cobalt compounds, one of the most interesting series among inorganic substances. This masterly work, conducted with the collaboration of F. A. Genth, shed much light upon the puzzling nature of the complex compounds in general and laid the foundation for one of the most elaborate of modern chemical theories. The following years (1861–4) saw him engaged upon a careful study of the platinum metals, upon which he was engaged when he accepted the call to Cambridge in 1863. Shortly afterward (1864) he published for the first time a description of his use of the voltaic current for depositing copper and nickel in such a manner that

[1] Reprinted from *Science*, vol. XXIX, pp. 101–103. Jan. 15, 1909. Professor Gibbs died 9 December, 1908, having been an Honorary Member of the Academy since 1890.

the deposited metals could be directly weighed — thus providing a simple and exact quantitative method for the analysis of substances containing these metals. The fact that a German, Luckow, afterwards stated that he had used the method for copper before Gibbs had used it, does not detract from the real originality of Gibbs's idea; for Luckow's work was wholly unknown to Gibbs.

From time to time throughout all Gibbs's long period of scientific activity there appeared papers from his pen describing other new and useful methods of quantitative analysis, many of which have been incorporated into the common analytical practise of to-day. For example, his sand-filtering device of 1867 may be said to have been a forerunner of the present admirable apparatus perfected by Gooch and Munroe.

Not long after coming to Harvard, Gibbs turned his attention to the precise use of the spectrometer in chemical investigations, and this work was continued in 1875. Throughout all this time the subject of his work with Genth was only half dormant in his mind, and occasional theoretical or experimental papers concerning the peculiar nature of cobaltamine compounds showed his devotion to his early choice.

Not content with the paradoxes and puzzles offered by these complex bases, or with the other abstruse subjects mentioned, he attacked in succeeding years the complex inorganic acids, composed of various combinations of tungstic, molybdic, phosphoric, arsenic, antimonic and vanadic acids. One cannot help wishing, upon studying his patient and careful quest among the bewildering phenomena manifested by these singular substances, that he had had the assistance of modern physical chemistry. But our present knowledge was not then at any one's disposal, and Gibbs did his best with the means at his command, devoting himself for a number of years to the expansion and systematizing of the work in this but slightly cultivated field.

From inorganic chemistry he later turned for a short time to a very different subject, undertaking with H. A. Hare and E. T. Reichert, a systematic study of the action of definitely related chemical compounds upon animals. This research, which appeared in 1891 and 1892, together with occasional previous papers upon organic chemistry, afforded evidence of the breadth of his interest.

Keen as his sense of the importance of physiological chemistry became. it was not keen enough to divert him wholly from his devotion to the rarer substances of the inorganic world, as his following paper on the oxides contained in cerite, samarskite, gadolinite and fergusonite testified.

Although Wolcott Gibbs was essentially an experimentalist, he was one of the first of Amercan chemists to appreciate the importance of thermodyn-

amics. His large library contained all the standard works upon heat, and his influence was the prime factor in having caused the award of the Rumford medal to J. Willard Gibbs as early as 1880, long before the world at large appreciated the fundamental character of the work of the great New Haven physicist. Wolcott Gibbs served on the Rumford Committee of the American Academy for thirty years (1864–1894), and in many other ways did his best to aid the progress of science in America. He was for a time president of the National Academy of Sciences, until ill health enforced his resignation; and he served also as president of the American Association for the Advancement of Science.

Not only at home, but also abroad, his eminence was worthily recognized. His election to honorary membership in the German Chemical Society in 1883 and to corresponding membership in the Royal Prussian Academy in 1885 is perhaps the most striking evidence of the foreign appreciation of his work. No other American chemist has ever attained to either of these high honors.

The brief autobiography published in the issue of *Science* for December 18, 1908, gives the chief events in his quiet daily life. His manhood was spent partly in New York, partly in Cambridge, and finally, during recent years, among his cherished flowers at his home on Gibbs Avenue near the First Beach at Newport, R. I. The circumstances of his early academic life brought him into close contact with but few students. This is the more to be regretted because his enthusiastic spirit, his tireless energy, his generous recognition of everything good and best of all his warm human friendship endeared him to all who knew him. Those who were thus fortunate, whether students or colleagues, will always devotedly treasure his memory; and his place as a pioneer of science in America will always be secure.

MEMOIR OF SIMON NEWCOMB.[1]

By G. W. Hill.

Professor Newcomb has narrated at considerable length the personal incidents of his scientific career in his book "The Reminiscences of an Astronomer," and to that source the reader desirous of knowing them may be referred. Here it is intended to note only the scope and characteristics of his more important contributions to astronomy. While Professor New-

[1] Reprinted from *Science*, vol. XXIX, pp. 357–358. Sept. 17, 1909. The author is an Honorary Member of the Academy.

Professor Newcomb died 12 July, 1909, having been an Honorary Member of the Academy since 1891.

comb wished always to be accounted a mathematician, his work seems motived by its possible application to astronomy, and no very weighty contribution from his pen has accrued to pure mathematics.

While still an assistant in the office of the *American Ephemeris*, then at Cambridge, Mass., Professor Newcomb began his career as an astronomer by discussing the question of the origin of the minor planets. Induced by too great confidence in the law of Bode as to the relations of the mean distances of the major planets, Olbers had ventured to put forward the hypothesis that the minor planets were the fragments resulting from the disruption of a single major planet. This hypothesis necessitated the condition that the orbits of the minor planets at some past epoch must have had a point in common. By computing the secular variations of the elements of the minor planets, Professor Newcomb showed that at no time could this condition have been fulfilled. Thus there was no reason for entertaining the theory of Olbers.

After Professor Newcomb's appointment to a professorship of mathematics in the U. S. Navy and his removal to Washington, he was much engaged with the instruments of the U. S. Naval Observatory, chiefly the Pistor and Martin's transit circle, but found time to investigate the distance of the sun, concluded from all the methods. His result for the constant of solar parallax was 8″. 848, a value adopted in nearly all the ephemerides for quite a lengthy period. It is too large chiefly on account of the large weight attributed to the determination from Mars, whose observation is subject to systematic errors, at that time unsuspected.

About the same time, Professor Newcomb undertook the investigation of the orbit of Neptune and constructed general tables of its motion. As material he had the two observations of Lalande and those of eighteen years following the discovery of the planet. This investigation, published in the *Smithsonian Contributions to Knowledge*, met an urgent need of practical astronomy at that time.

As the secure reduction of astronomical observations is a matter of prime importance, Professor Newcomb contributed to the *Washington Observations* for 1870 an appendix dealing with the right ascensions of the equatorial fundamental stars. His aim was to eliminate as far as possible systematic errors of a personal or local nature and thus obtain a homogeneous system. This was an admirably conducted investigation and has served as a foundation for whatever has been since accomplished in this subject.

The elegant method of treating the motion of the moon by Delaunay, published in 1860, led Professor Newcomb to consider this subject; thus we have his memoir in *Liouville's Journal* for 1871 on the planetary perturbations of the moon. The investigation is very neat, regard being had to the

early epoch of its composition, but the final equations derived are precisely those which result from Delaunay's method.

Having treated Neptune, Professor Newcomb next undertook a similar piece of work for the adjacent planet Uranus. This was a heavier task than its predecessor on account of the longer period covered by the observations. These theories of the two planets have been superseded by the investigations of Professor Newcomb while director of the *American Ephemeris*, but that of Uranus was welcomed by astronomers as a great improvement on the discussion of Bouvard. As in the case of Neptune, the investigations of Uranus appear in the *Smithsonian Contributions to Knowledge*.

In the same collection for the following year, Professor Newcomb has a memoir on the general integrals of planetary motion. The aim of this paper is to show how to avoid powers of the time as multipliers of the different portions of the algebraic expressions arrived at. The thus modified expressions have since received the name of Lindstedt's series and are the chief subject of investigation in M. Poincaré's work in the line of celestial mechanics. This paper was a worthy beginning for what was to follow.

Only a few years after the introduction of Hansen's lunar tables for computing the places for the ephemerides, it was seen that observation was marching away from them. From the character of the deviation they could only be attributed to an imperfect determination by Hansen of the secular and long-period terms. Always interested in the theory of the moon, Professor Newcomb undertook to see what light could be thrown on the matter by observations made before the epoch of 1750, chiefly in the form of times of beginning or ending of solar and lunar eclipses and occultations. This involved a heavy load of numerical computation and a careful research for material in the libraries and observatories of Europe. The results of this labor appear in an appendix to the *Washington Observations* for 1875. The memoir led to large modifications in our estimation of the value of Hansen's theory, and it still must serve as a foundation to all future investigations in the subject.

In 1877, Professor J. H. C. Coffin was retired from the U. S. Navy on account of age, and thus the *American Ephemeris* was left without a head. Professor Newcomb was appointed to the vacant place. He immediately formed the grandiose scheme of reforming nearly all the fundamental data involved in the construction of an astronomical ephemeris. One would have been inclined to predict the failure or, at least, only partial success of such a scheme; but Professor Newcomb, by his skillful management, came very near to complete success during his lifetime; only tables of the moon were lacking to the rounding of the plan. It must, however, be noted that he was fortunate in finding a few men ready to hand in relieving him not only of

the drudgery of numerical calculations, but, in some cases, of devising methods. To aid matters, he founded a collection called *The Astronomical Papers of the American Ephemeris* to contain all the memoirs the carrying out the scheme should give occasion to. A large proportion of these memoirs is the work of Professor Newcomb. So numerous are they that we must be content with noticing only the more striking and important ones.

The transits of Mercury from 1677 to 1881 were discussed, with the principal result of corroborating Leverrier's assertion of 40″ in the secular motion of the perihelion unaccounted for.

In the years 1880-1882, Professor Newcomb made a determination of the velocity of light by the Foucault method. The construction of the instrument and the mode of handling it enabled a very large angle of deviation to be obtained; and thus an extraordinary degree of precision in the result was hoped for. Although this hope was not completely fulfilled, nevertheless the concluded value is far in advance of all previous determinations.

Shortly after, Professor Newcomb exhaustively treated the transits of Venus in 1761 and 1769 with the object of obtaining the constant of mutation from material afforded by observations with the transit circles of Greenwich and Washington.

Professor Newcomb deemed that improvements could be made in the mode of deriving the periodic expressions needed in the subject of planetary perturbations. His method of treatment is elaborated in a memoir in the *American Journal of Mathematics*, Vol. III, and, at greater length, in a second memoir in the *Astronomical Papers*, Vol. III; and, finally, application is made to the four interior planets in a third memoir contained in the latter volume. For certain long-period inequalities in these planets it was found convenient to employ expressions involving time-arguments; this led to the composition of two memoirs in Vol. V, of the same collection.

The secular variations of the elements of these planets are derived and the mass of Jupiter determined from observations of Polyrhymnia in the two following memoirs of the same volume.

Professor Asaph Hall having found that there was a rather rapid retrograde motion of the line of apsides of Hyperion, Professor Newcomb explained this from the point of view of the variation of elements. By an inadvertency at the very end of his memoir he failed to obtain a correct value for the mass of Titan, the disturbing body.

The completion of these preliminary investigations enabled Professor Newcomb to proceed at once to the composition of a memoir of the elements of the four inner planets and the fundamental constants of astronomy, which appeared as a supplement to the *American Ephemeris* for 1897. This memoir contains the data on which are founded the tables of these planets,

published shortly after. In 1899, Professor Newcomb completed his work on the six major planets he had undertaken to revise by the publication of tables of Uranus and Neptune.

While all these investigations in the planetary theories were going on, Professor Newcomb must have found time for attacking his subject of predilection, the lunar theory, for we have a lengthy memoir by him on the action of the planets on the moon, contained in the volume last mentioned. This paper must have cost him an enormous amount of labor; he seems to be determined that no inequality of sensible magnitude should escape him.

The tables of the planets being out of the way, Professor Newcomb next turned his attention to the fixed stars. Being present at the Paris Conference of 1896 on a common international catalogue of fundamental stars, he obtained the assignment of the subject of precession as his share of the work to be undertaken. Within a year he had the work done, having derived a value of the principal constant involved which is probably as good as the condition of the data at the time allowed.

This memoir is naturally followed by another containing a catalogue of more than 1,500 stars reduced to an absolute system and to be employed as fundamental.

In March, 1897, Professor Newcomb, having arrived at the age limit, was retired from the office of the *American Ephemeris*. Many of his unfinished jobs were carried to completion under the nominal superintendence of others.

At the foundation of the Carnegie Institution of Washington, Professor Newcomb secured the privilege of prosecuting his researches on the motion of the moon under its auspices. Here, until the end of his life, he labored assisted by a small but very able corps of assistants. Although the period of time was short, a long memoir on the planetary inequalities has appeared.

The last contribution of Professor Newcomb to science is an article in the *Monthly Notices* for January, 1909, exhibiting the deviations of the moon's mean longitude from the best theory that, so far, has been devised.

In the intervals of leisure between his labors of a more technical kind, Professor Newcomb composed a book on "Popular Astronomy." Although the rapid advance of the science in the more than thirty years since its publication has caused it to fall behind, it still remains the best composition on the subject.

Professor Newcomb contributed a vast number of notes on almost every conceivable topic in astronomy and the allied sciences to the scientific periodicals. (In this connection it may be useful to state that the Royal Society of Canada has published a bibliography.) He had the management of the construction of tables for the Watson asteroids. He found time to

treat questions in economics and psychics and even wrote a novel. No matter how many tools he had in the fire, he was always ready to add to them. His journeys to observe total solar eclipses, transits of the interior planets and to collect scientific data from the observatories and libraries of Europe are too numerous for mention.

With almost universal consent, it is admitted that, for the last forty years of his life, Professor Newcomb stood at the head of the cultivators of the astronomy of position. And he did not have to complain of lack of appreciation by his fellows; after he had got fairly started in his scientific career, a continual flow of medals, prizes, degrees and honorary memberships in scientific societies came for his reception, till the possibilities were exhausted. His departure leaves a great gap in the band of astronomers. It will be long before we again have one of equal untiring energy.

MEMOIR OF KAKICHI MITSUKURI.[1]

By Bashford Dean.

We are to record to-night, and with sincere regret, the death of Professor Kakichi Mitsukuri, the most distinguished zoölogist of Japan, honorary member in the Academy since 1908 and a corresponding member since 1900. He was to us who are zoölogists more than an honorary member, for he was with us at our meetings on several occasions, and to a number of our academicians he was a close and valued friend. Thus to Professor Wilson, one time chairman of the Biological Section and president of the Academy, he was a fellow student at Johns Hopkins and at Yale. To those of us who have visited Japan, he was literally the best of friends, for there was no favor which he left undone, and this is to say much, for his influence reached far and wide, from the Hokkaido to remote Tosa. Everywhere he seemed to have effective friends, from Governors of Provinces whose suite would come in state to the railroad station, to fisher-people whose personal property appeared to begin and end with a sampan.

Mitsukuri owed his training in large part to the United States. He came here as a youth of fifteen, went to Sheffield Scientific School and later to Johns Hopkins. There he was appointed fellow in zoölogy in 1881. In 1883 he was given his degree. Before this, however, he had returned to Japan and had become head of the department of zoölogy in Tokyo Uni-

[1] Dr. Mitsukuri died 12 September, 1909, having been an Honorary Member of the Academy since 1908. This memorial was read at the Academy meeting of January 3, 1910.

versity. In this position he supplanted Professor Whitman and was one of the first of his countrymen to carry on the highest educational work on foreign lines without the help of Europeans. Mitsukuri trained most of the younger generation of Japanese zoölogists, and he sacrificed to no little degree his important researches in his time-consuming devotion to his pupils. He was in the laboratory at all times and always accessible, and he had an affectionate friendliness of manner which means so much to the student, be he foreign or Japanese. Then, too, he had the gift executive; he accomplished things,— in many regards he reminded one of Spencer F. Baird. He could make converts who worked, he made friends who supported his plans, he could be diplomatic without sacrificing an atom of principle, he had zoölogical argosies sailing to all parts of the island empire, even to remote Tai Wan or to Sagahlien, he was big enough not to despise applied zoölogy, even to be willing to lend it his own strong hand. As an instance of this he showed keen interest in the pearl problem — which his pupil Dr. Nishikawa finally solved. And he sacrificed much of his time in accepting a commissionership in the Behring Sea seal inquiry at the time it was causing international unrest. To zoölogists, Mitsukuri will ever be known for his researches in reptilian embryology, for his work was accurate, philosophical in its bearings and carried out with artistic completeness. In a word, Mitsukuri did much and in many directions. Perhaps at the end if we could have read his mind we would have found that what he prized most highly in his life work was his successful patriotism, not at home, of course, where all are born patriotic, but in teaching to a foreign world the ideals of Great Japan. For everyone who knew Mitsukuri knew something of the real Japan, and from it came to many Europeans a higher regard and respect for the Japanese, whether poor or rich, peasant or scholar. We may altogether safely say that in the death of Mitsukuri our Academy has lost a member whom it was an honor to honor.

MEMOIR OF JOHN HENRY CASWELL.[1]

By James F. Kemp.

John Henry Caswell, in whose memory these lines are prepared, was born in New York City December twenty-seventh, eighteen hundred forty six. With the exception of several years of student life abroad and of occasional

[1] Dr. Caswell died October 16, 1909, having been an Active Member of the Academy since 1869. This memorial was read at the Academy meeting of December 6, 1909.

journeys for the enjoyment of travel, his native city was his continued home and with its institutions and its scientific and philanthropic work he was identified during his sixty-three years of useful life.

On completing his preparation in the schools, Mr. Caswell entered Columbia College in 1861 and graduated in 1865. During his college course he came under the influence of Professor Charles A. Joy, then occupying the chair of chemistry, a man of enthusiastic devotion to science and of especial interest in mineralogy. Professor Joy had earlier received European training; he was an old student of Bunsen's and was one who turned eagerly to the renewal of his pleasant relations with his old professors in Germany. On Mr. Caswell's graduation he accompanied Professor Joy to Europe, and in the autumn was enrolled in the famous old Mining Academy at Frieberg. Three very happy years of study ensued, varied during the vacations by trips to the mining districts of Norway and Sweden and of the Hartz Mountains. During his residence at Freiberg, Mr. Caswell had as fellow-students Arnold Hague now of the United States Geological Survey, Professor H. B. Cornwall of Princeton and A. D. Hodges, Jr., later to be an engineer of exceptional influence in the mining development of this country. All three remained his lifelong friends. Mr. Caswell, who had from boyhood loved natural science like many another Freiberger, became still more strongly enamoured of mineralogy and found in its pursuit one of the great enjoyments of his life.

In 1864, the School of Mines of Columbia College was established so that on his return to New York in 1868 Mr. Caswell became assistant in mineralogy to Professor Thomas Egleston. For three years he held this position, but the death of his father in 1871 compelled him for the time being to resign his scientific work and devote himself to the business of the estate. While connected with the Columbia School of Mines the "Wanderlust" did not fail to seize him, and it was so strong that his summer months were spent with his friend Mr. Hodges in the mines of what is now Colorado and in Nevada and California.

Mr. Caswell continued his interest in mineralogy despite his immersion in business cares. In 1874 he resumed his position in the School of Mines and held it for three years. During this period Henry Newton and Walter P. Jenney were engaged in the geological survey of the Black Hills of Dakota. Their collections embraced great numbers of igneous rocks which were obviously of unusual scientific interest. When they came to New York to work up their results in Professor Newberry's laboratory, they persuaded Mr. Caswell, then in the department of mineralogy, to undertake the microscopic investigation of this material. Petrography was in its infancy. A few Americans returning from European study had learned something of it abroad, and one or two Americans had busied themselves in its pursuit

without the advantages of foreign training. Practically the only published work before this time is contained in the observations of A. A. Julien on the rocks of Wisconsin and in the papers of E. S. Dana on the traps of the Connecticut Valley. Microscopes were far less convenient instruments than they have since become, and the study of the optics of crystals and the use of polarized light, always a difficult subject, presented exceptional obscurites. Nevertheless Mr. Caswell set to work, and, with the sympathetic aid of Professor Egleston and Dr. Julien and with the help of Dr. Waller in the preparation of chemical analyses, became, as the results prove, extremely skillful and accurate.

It is also worthy of remark that at this time the headquarters of the Fortieth Parallel Survey were in New York, so that Mr. Caswell found himself in association with his old friend and fellow-student at Freiberg, Mr. Arnold Hague. In the preface of the sixth volume of the reports of this survey, Professor Zirkel, in addressing Clarence King, speaks as follows: "I cannot fail to gratefully acknowledge how much invaluable assistance I owe to you and to your excellent fellow-workmen, Messrs. S. F. Emmons and Arnold Hague. You well remember that happy time in New York when for many weeks we made together the preliminary examination of that vast collection of rocks, you had gathered under such difficulties, but with such eminent geological taste." We can well imagine the enthusiasm with which this subject was taken up, under the stimulus of Professor Zirkel's personality, since there are few teachers who have become so universally esteemed and beloved as himself. Under these circumstances the study of the Black Hills rocks was begun by Mr. Caswell, and his report furnishes one of the most important chapters in this invaluable work. The collection embraced a series of rhyolites, trachytes and, what was of extraordinary interest at the time, phonolites, the first of this rare type to be identified in America. Now, nephelite, the diagnostic constituent of phonolites, is one of the most elusive of the more important rock-making minerals and time and again in these early years had either slipped by the older observers or else had been confounded with apatite. It was, however, correctly determined by Mr. Caswell and its recognition enabled him to describe and illustrate this new and interesting occurrence.

There is one other feature of Mr. Caswell's report which demands mention, and that is found in the plates, which were based upon his drawings from the microscope. They are of singular fidelity and beauty. Although prepared at so early a date they have been rarely if at all surpassed in later years.

The work upon all branches of the Black Hills geology was delayed in publication by the unfortunate jealousies then prevailing among the four

national surveys, and was still further postponed by the untimely death of Henry Newton in Deadwood, August 5th, 1877. Not until three years later, and then under the skilful and sympathetic editorship of G. K. Gilbert, was the volume issued. Nevertheless Mr. Caswell's work on the petrography of the Hills will always be associated in the minds of students of the subject with Zirkel's Report for the Fortieth Parallel Survey (1876) and George Hawes's Lithology of New Hampshire (1878).

In 1877 business responsibilities again drew Mr. Caswell away from his position as teacher of mineralogy, and he reluctantly gave up his prospect of a professor's chair. None the less, however, his interest in mineralogy continued all his life, and his collection, the delight of his leisure hours, became an exceedingly choice one. He kept up his connection with fellow mineralogists all over the world and has had one mineral "caswellite" named after him by his fellow-student at Columbia and life-long friend, Professor Albert H. Chester, whom, in fact, he had succeeded when becoming assistant to Professor Egleston in 1869.

In his later years, Mr. Caswell occupied many positions of trust in New York. For years he was on the Finance Committee of the New York Academy of Sciences. At his decease, October 16th, 1909, but six active members exceeded him in length of membership. He was a vestry-man of Trinity Church and was treasurer of several Church Institutions, for one of which he raised a fund of over $200,000. He was a member of the Century Association, was deeply interested in the Grolier Club and was a supporter of many scientific societies in the Metropolis.

In character, Mr. Caswell was marked by exceptional modesty, sincerity and faithfulness. All through his life he was marked by his loyalty to his friends, not only those of his student days but even those of his boyhood. He was ever ready to be of assistance in scientific matters and was constantly helpful in other relations to those who sought his aid. All who were privileged to have known him, will cherish his remembrance through life.

In eighteen seventy-two, Mr. Caswell was married to Mary B. Curtiss, who survives him after many years of close and sympathetic companionship.

THE ORGANIZATION OF THE NEW YORK ACADEMY OF SCIENCES.

THE ORIGINAL CHARTER.

AN ACT TO INCORPORATE THE

LYCEUM OF NATURAL HISTORY IN THE CITY OF NEW YORK.

Passed April 20, 1818.

WHEREAS, The members of the Lyceum of Natural History have petitioned for an act of incorporation, and the Legislature, impressed with the importance of the study of Natural History, as connected with the wants, the comforts and the happiness of mankind, and conceiving it their duty to encourage all laudable attempts to promote the progress of science in this State — therefore,

1. *Be it enacted by the People of the State of New York represented in Senate and Assembly,* That Samuel L. Mitchill, Casper W. Eddy, Frederick C. Schaeffer, Nathaniel Paulding, William Cooper, Benjamin P. Kissam, John Torrey, William Cumberland, D'Jurco V. Knevels, James Clements and James Pierce, and such other persons as now are, and may from time to time become members, shall be, and hereby are constituted a body corporate and politic, by the name of LYCEUM OF NATURAL HISTORY IN THE CITY OF NEW YORK, and that by that name they shall have perpetual succession, and shall be persons capable of suing and being sued, pleading and being impleaded, answering and being answered unto, defending and being defended, in all courts and places whatsoever; and may have a common seal, with power to alter the same from time to time; and shall be capable of purchasing, taking, holding, and enjoying to them and their successors, any real estate in fee simple or otherwise, and any goods, chattels, and personal estate, and of selling, leasing, or otherwise disposing of said real or personal estate, or any part thereof, at their will and pleasure: *Provided always,* that the clear annual value or income of such real or personal estate shall not exceed the sum of five thousand dollars: *Provided,* however, that the funds of the said Corporation shall be used and appropriated to the promotion of the objects stated in the preamble to this act, and those only.

2. *And be it further enacted,* That the said Society shall from time to time, forever hereafter, have power to make, constitute, ordain, and estab-

lish such by-laws and regulations as they shall judge proper, for the election of their officers; for prescribing their respective functions, and the mode of discharging the same; for the admission of new members; for the government of the officers and members thereof; for collecting annual contributions from the members towards the funds thereof; for regulating the times and places of meeting of the said Society; for suspending or expelling such members as shall neglect or refuse to comply with the by-laws or regulations, and for the managing or directing the affairs and concerns of the said Society: *Provided* such by-laws and regulations be not repugnant to the Constitution and laws of this State or of the United States.

3. *And be it further enacted*, That the officers of the said Society shall consist of a President and two Vice-Presidents, a Corresponding Secretary, a Recording Secretary, a Treasurer, and five Curators, and such other officers as the Society may judge necessary; who shall be annually chosen, and who shall continue in office for one year, or until others be elected in their stead; that if the annual election shall not be held at any of the days for that purpose appointed, it shall be lawful to make such election at any other day; and that five members of the said Society, assembling at the place and time designated for that purpose by any by-law or regulation of the Society, shall constitute a legal meeting thereof.

4. *And be it further enacted*, That Samuel L. Mitchill shall be the President; Casper W. Eddy the First Vice-President; Frederick C. Schaeffer the Second Vice-President; Nathaniel Paulding, Corresponding Secretary; William Cooper, Recording Secretary; Benjamin P. Kissam, Treasurer, and John Torrey, William Cumberland, D'Jurco V. Knevels, James Clements, and James Pierce, Curators; severally to be the first officers of the said Corporation, who shall hold their respective offices until the twenty-third day of February next, and until others shall be chosen in their places.

5. *And be it further enacted*, That the present Constitution of the said Association shall, after passing of this Act, continue to be the Constitution thereof; and that no alteration shall be made therein, unless by a vote to that effect of three-fourths of the resident members, and upon the request in writing of one-third of such resident members, and submitted at least one month before any vote shall be taken thereupon.

State of New York, Secretary's Office.

I CERTIFY the preceding to be a true copy of an original Act of the Legislature of this State, on file in this Office.

ARCH'D CAMPBELL,
Dep. Sec'y.

ALBANY, *April* 29, 1818.

ORDER OF COURT.

ORDER OF THE SUPREME COURT OF THE STATE OF NEW YORK TO CHANGE THE NAME OF

THE LYCEUM OF NATURAL HISTORY IN THE CITY OF NEW YORK

TO

THE NEW YORK ACADEMY OF SCIENCES.

WHEREAS, in pursuance of the vote and proceedings of this Corporation to change the corporate name thereof from "The Lyceum of Natural History in the City of New York" to "The New York Academy of Sciences," which vote and proceedings appear to record, an application has been made in behalf of said Corporation to the Supreme Court of the State of New York to legalize and authorize such change, according to the statute in such case provided, by Chittenden & Hubbard, acting as the attorneys of the Corporation, and the said Supreme Court, on the 5th day of January, 1876, made the following order upon such application in the premises, viz:

At a special term of the Supreme Court of the State of New York, held at the Chambers thereof, in the County Court House, in the City of New York, the 5th day of January, 1876:

Present — HON. GEO. C. BARRETT, *Justice*.

In the matter of the application of the Lyceum of Natural History in the City of New York to authorize it to assume the corporate name of the New York Academy of Sciences.

On reading and filing the petition of the Lyceum of Natural History in the City of New York, duly verified by John S. Newberry, the President and chief officer of said Corporation, to authorize it to assume the corporate name of the New York Academy of Sciences, duly setting forth the grounds of said application, and on reading and filing the affidavit of Geo. W. Quackenbush, showing that notice of such application had been duly published for six weeks in the State paper, to wit, *The Albany Evening Journal*, and the affidavit of David S. Owen, showing that notice of such application has also been duly published in the proper newspaper of the County of New York, in which county said Corporation had its business office, to wit, in *The Daily Register*, by which it appears to my satisfaction that such notice has been so published, and on reading and filing the affidavits of Robert H. Browne and J. S. Newberry, thereunto annexed, by which it appears to my satisfaction that the application is made in pursuance of a resolution of the managers of said Corporation to that end named, and there appearing to me to be no reasonable objection to said Corporation so changing its name as prayed in said petition: Now on motion of Grosvenor S. Hubbard, of Counsel for Petitioner, it is

Ordered, That the Lyceum of Natural History in the City of New York be and is hereby authorized to assume the corporate name of The New York Academy of Sciences.

Indorsed: Filed January 5, 1876,

A copy.

WM. WALSH, *Clerk*.

Resolution of THE ACADEMY, *accepting the order of the Court, passed February* 21, 1876.

And whereas, The order hath been published as therein required, and all the proceedings necessary to carry out the same have been had, Therefore:

Resolved, That the foregoing order be and the same is hereby accepted and adopted by this Corporation, and that in conformity therewith the corporate name thereof, from and after the adoption of the vote and resolution herein above referred to, be and the same is hereby declared to be

THE NEW YORK ACADEMY OF SCIENCES.

THE AMENDED CHARTER.

MARCH 19, 1902.

CHAPTER 181 OF THE LAWS OF 1902.

AN ACT to amend chapter one hundred and ninety-seven of the laws of eighteen hundred and eighteen, entitled "An act to incorporate the Lyceum of Natural History in the City of New York," a Corporation now known as The New York Academy of Sciences and to extend the powers of said Corporation.

(Became a law March 19, 1902, with the approval of the Governor. Passed, three-fifths being present.)

The People of the State of New York, represented in Senate and Assembly, do enact as follows:

SECTION I. The Corporation incorporated by chapter one hundred and ninety-seven of the laws of eighteen hundred and eighteen, entitled "An act to incorporate the Lyceum of Natural History in the City of New York," and formerly known by that name, but now known as The New York Academy of Sciences through change of name pursuant to order made by the supreme court at the city and county of New York, on January fifth, eighteen hundred and seventy-six, is hereby authorized and empowered to raise money for, and to erect and maintain, a building in the city of New York for its use, and in which also at its option other scientific societies may be admitted and have their headquarters upon such terms as said Corporation may make with them, portions of which building may be also rented out by said Corporation for any lawful uses for the purposes of obtaining income for the maintenance of such building and for the promotion of the objects of the Corporation; to establish, own, equip, and administer a public library, and a museum having especial reference to scientific subjects; to publish communications, transactions, scientific works, and periodicals; to give scientific instruction by lectures or otherwise; to encourage the advancement of scientific research and discovery, by gifts of money, prizes, or other assistance thereto. The building, or rooms, of said Corporation in the city of New York used exclusively for library or scientific purposes shall be subject to the provisions and be entitled to the benefits of subdivision seven of section four of chapter nine hundred and eight of the laws of eighteen hundred and ninety-six, as amended.

SECTION II. The said Corporation shall from time to time forever hereafter have power to make, constitute, ordain, and establish such by-laws

and regulations as it shall judge proper for the election of its officers; for prescribing their respective functions, and the mode of discharging the same; for the admission of new members; for the government of officers and members thereof; for collecting dues and contributions towards the funds thereof; for regulating the times and places of meeting of said Corporation; for suspending or expelling such members as shall neglect or refuse to comply with the by-laws or regulations, and for managing or directing the affairs or concerns of the said Corporation: and may from time to time alter or modify its constitution, by-laws, rules, and regulations.

SECTION III. The officers of the said Corporation shall consist of a president and two or more vice-presidents, a corresponding secretary, a recording secretary, a treasurer, and such other officers as the Corporation may judge necessary; who shall be chosen in the manner and for the terms prescribed by the constitution of the said Corporation.

SECTION IV. The present constitution of the said Corporation shall, after the passage of this act, continue to be the constitution thereof until amended as herein provided. Such constitution as may be adopted by a vote of not less than three-quarters of such resident members and fellows of the said New York Academy of Sciences as shall be present at a meeting thereof, called by the Recording Secretary for that purpose, within forty days after the passage of this act, by written notice duly mailed, postage prepaid, and addressed to each fellow and resident member at least ten days before such meeting, at his last known place of residence, with street and number when known, which meeting shall be held within three months after the passage of this act, shall be thereafter the constitution of the said New York Academy of Sciences, subject to alteration or amendment in the manner provided by such constitution.

SECTION V. The said Corporation shall have power to consolidate, to unite, to co-operate, or to ally itself with any other society or association in the city of New York organized for the promotion of the knowledge or the study of any science, or of research therein, and for this purpose to receive, hold, and administer real and personal property for the uses of such consolidation, union, co-operation, or alliance subject to such terms and regulations as may be agreed upon with such associations or societies.

SECTION VI. This act shall take effect immediately.

STATE OF NEW YORK,

OFFICE OF THE SECRETARY OF STATE.

I have compared the preceding with the original law on file in this office, and do hereby certify that the same is a correct transcript therefrom, and the whole of said original law.

Given under my hand and the seal of office of the Secretary of State, at the city of Albany, this eighth day of April, in the year one thousand nine hundred and two.

JOHN T. McDONOUGH,
Secretary of State.

CONSTITUTION.

ADOPTED, APRIL 24, 1902, AND AMENDED AT SUBSEQUENT TIMES.

ARTICLE I. The name of this Corporation shall be The New York Academy of Sciences. Its object shall be the advancement and diffusion of scientific knowledge, and the center of its activities shall be in the City of New York.

ARTICLE II. The Academy shall consist of five classes of members, namely: Active Members, Fellows, Associate Members, Corresponding Members and Honorary Members. Active Members shall be the members of the Corporation who live in or near the City of New York, or who, having removed to a distance, desire to retain their connection with the Academy. Fellows shall be chosen from the Active Members in virtue of their scientific attainments. Corresponding and Honorary Members shall be chosen from among the men of science of the world who have attained distinction as investigators. The number of Corresponding Members shall not exceed two hundred, and the number of Honorary Members shall not exceed fifty.

ARTICLE III. None but Fellows and Active Members who have paid their dues up to and including the last fiscal year shall be entitled to vote or to hold office in the Academy.

ARTICLE IV. The officers of the Academy shall be a President, as many Vice-Presidents as there are sections of the Academy, a Corresponding Secretary, a Recording Secretary, a Treasurer, a Librarian, an Editor, six elected Councilors and one additional Councilor from each allied society or association. The annual election shall be held on the third Monday in December, the officers then chosen to take office at the first meeting in January following.

There shall also be elected at the same time a Finance Committee of three.

ARTICLE V. The officers named in Article IV shall constitute a Council, which shall be the executive body of the Academy with general control over its affairs, including the power to fill *ad interim* any vacancies that may occur in the offices. Past Presidents of the Academy shall be *ex-officio* members of the Council.

ARTICLE VI. Societies organized for the study of any branch of science

may become allied with the New York Academy of Sciences by consent of the Council. Members of allied societies may become Active Members of the Academy by paying the Academy's annual fee, but as members of an allied society they shall be Associate Members with the rights and privileges of other Associate Members, except the receipt of its publications. Each allied society shall have the right to delegate one of its members, who is also an Active Member of the Academy, to the Council of the Academy, and such delegate shall have all the rights and privileges of other Councilors.

ARTICLE VII. The President and Vice-Presidents shall not be eligible to more than one re-election until three years after retiring from office; the Secretaries and Treasurer shall be eligible to re-election without limitation. The President, Vice-presidents and Secretaries shall be Fellows. The terms of office of elected Councilors shall be three years, and these officers shall be so grouped that two, at least one of whom shall be a Fellow, shall be elected and two retired each year. Councilors shall not be eligible to re-election until after the expiration of one year.

ARTICLE VII. The election of officers shall be by ballot, and the candidates having the greatest number of votes shall be declared duly elected.

ARTICLE IX. Ten members, the majority of whom shall be Fellows, shall form a quorum at any meeting of the Academy at which business is transacted.

ARTICLE X. The Academy shall establish by-laws, and may amend them from time to time as therein provided.

ARTICLE XI. This Constitution may be amended by a vote of not less than three fourths of the fellows and three fourths of the active members present and voting at a regular business meeting of the Academy, provided that such amendment shall be publicly submitted in writing at the preceding business meeting, and provided also that the Recording Secretary shall send a notice of the proposed amendment at least ten days before the meeting, at which a vote shall be taken, to each Fellow and Active Member entitled to vote.

BY-LAWS.

AS ADOPTED, OCTOBER 6, 1902, AND AMENDED AT SUBSEQUENT TIMES.

CHAPTER I.

OFFICERS.

1. *President.* It shall be the duty of the President to preside at the business and special meetings of the Academy; he shall exercise the customary duties of a presiding officer.

2. *Vice-Presidents.* In the absence of the President, the senior Vice-President, in order of Fellowship, shall act as the presiding officer.

3. *Corresponding Secretary.* The Corresponding Secretary shall keep a corrected list of the Honorary and Corresponding Members, their titles and addresses, and shall conduct all correspondence with them. He shall make a report at the Annual Meeting.

4. *Recording Secretary.* The Recording Secretary shall keep the minutes of the Academy proceedings; he shall have charge of all documents belonging to the Academy, and of its corporate seal, which he shall affix and attest as directed by the Council; he shall keep a corrected list of the Active Members and Fellows, and shall send them announcements of the Meetings of the Academy; he shall notify all Members and Fellows of their election, and committees of their appointment; he shall give notice to the Treasurer and to the Council of matters requiring their action, and shall bring before the Academy business presented by the Council. He shall make a report at the Annual Meeting.

5. *Treasurer.* The Treasurer shall have charge, under the direction of the Council, of all moneys belonging to the Academy, and of their investment. He shall receive all fees, dues and contributions to the Academy, and any income that may accrue from property or investment; he shall report to the Council at its last meeting before the Annual Meeting the names of members in arrears; he shall keep the property of the Academy insured, and shall pay all debts against the Academy the discharge of which shall be ordered by the Council. He shall report to the Council from time to time the state of the finances, and at the Annual Meeting shall report to the Academy the receipts and expenditures for the entire year.

6. *Librarian.* The Librarian shall have charge of the library, under the general direction of the Library Committee of the Council, and shall conduct all correspondence respecting exchanges of the Academy. He shall make a report on the condition of the library at the Annual Meeting.

7. *Editor.* The editor shall have charge of the publications of the Academy, under the general direction of the Publication Committee of the Council. He shall make a report on the condition of the publications at the Annual Meeting.

Chapter II.

COUNCIL.

1. *Meetings.* The Council shall meet once a month, or at the call of the President. It shall have general charge of the affairs of the Academy.

2. *Quorum.* Five members of the Council shall constitute a quorum.

3. *Officers.* The President, Vice-Presidents and Recording Secretary of the Academy shall hold the same offices in the Council.

4. *Committees.* The Standing Committees of the Council shall be: (1) an Executive Committee consisting of the President, Treasurer, and Recording Secretary; (2) a Committee on Publications; (3) a Committee on the Library, and such other committees as from time to time shall be authorized by the Council. The action of these committees shall be subject to revision by the Council.

Chapter III.

FINANCE COMMITTEE.

The Finance Committee of the Academy shall audit the Annual Report of the Treasurer, and shall report on financial questions whenever called upon to do so by the Council.

Chapter IV.

ELECTIONS.

1. *Active Members.* (*a*) Active Members shall be nominated in writing to the Council by at least two active Members or Fellows. If approved by the Council, they may be elected at the succeeding business meeting.

(*b*) Any Active Member who, having removed to a distance from the city of New York, shall nevertheless express a desire to retain his connection with the Academy, may be placed by vote of the Council on a list of Non-resident Members. Such members shall relinquish the full privileges and obligations of Active Members. (*Vide* Chapters V and X.)

2. *Associate Members.* Workers in science may be elected to Associate Membership for a period of two years in the manner prescribed for Active Members. They shall not have the power to vote and shall not be eligible to election as fellows, but may receive the publications. At any time subsequent to their election they may assume the full privileges of Active Members by paying the dues of such Members.

3. *Fellows, Corresponding Members and Honorary Members.* Nominations for Fellows, Corresponding Members, and Honorary Members may be made in writing either to the Recording Secretary or to the Council at its meeting prior to the Annual Meeting. If approved by the Council, the nominees shall then be balloted for at the Annual Meeting.

4. *Officers.* Nominations for Officers, with the exception of Vice-

Presidents, may be sent in writing to the Recording Secretary, with the name of the proposer, at any time not less than thirty days before the Annual Meeting. Each section of the Academy shall nominate a candidate for Vice-President, who, on election, shall be Chairman of the section; the names of such nominees shall be sent to the Recording Secretary properly certified by the sectional secretaries, not less than thirty days before the Annual Meeting. The Council shall then prepare a list which shall be the regular ticket. This list shall be mailed to each Active Member and Fellow at least one week before the Annual Meeting. But any Active Member or Fellow entitled to vote shall be entitled to prepare and vote another ticket.

Chapter V.

DUES.

1. *Dues.* The annual dues of Active Members and Fellows shall be \$10, payable in advance at the time of the Annual Meeting; but new members elected after May 1, shall pay \$5 for the remainder of the fiscal year.

The annual dues of elected Associate Members shall be \$3, payable in advance at the time of the Annual Meeting.

Non-resident Members shall be exempt from dues, so long as they shall relinquish the privileges of Active Membership. (*Vide* Chapter X.)

2. *Members in Arrears.* If any Active Member or Fellow whose dues remain unpaid for more than one year, shall neglect or refuse to pay the same within three months after notification by the Treasurer, his name may be erased from the rolls by vote of the Council. Upon payment of his arrears, however, such person may be restored to Active Membership or Fellowship by vote of the Council.

3. *Renewal of Membership.* Any Active Member or Fellow who shall resign because of removal to a distance from the City of New York, or any Non-resident Member, may be restored by vote of the Council to Active Membership or Fellowship at any time upon application.

Chapter VI.

PATRONS, DONORS AND LIFE MEMBERS.

1. *Patrons.* Any person contributing at one time \$1000 to the general funds of the Academy shall be a Patron and, on election by the Council, shall enjoy all the privileges of Active Members.

2. *Donors.* Any person contributing \$50 or more annually to the general funds of the Academy shall be termed a Donor and, on election by the Council, shall enjoy all the privileges of Active Members.

3. *Life Members.* Any Active Member or Fellow contributing at one time $100 to the general funds of the Academy shall be a Life Member and shall thereafter be exempt from annual dues; and any Active Member or Fellow who has paid annual dues for twenty-five years or more may, upon his written request, be made a life member and be exempt from further payment of dues.

Chapter VII.

SECTIONS.

1. *Sections.* Sections devoted to special branches of Science may be established or discontinued by the Academy on the recommendation of the Council. The present sections of the Academy are the Section of Astronomy, Physics and Chemistry, the Section of Biology, the Section of Geology and Mineralogy and the Section of Anthropology and Psychology.

2. *Organization.* Each section of the Academy shall have a Chairman and a Secretary, who shall have charge of the meetings of their Section. The regular election of these officers shall take place at the October or November meeting of the section, the officers then chosen to take office at the first meeting in January following.

3. *Affiliation.* Members of scientific societies affiliated with the Academy, and members of the Scientific Alliance, or men of science introduced by members of the Academy, may attend the meetings and present papers under the general regulations of the Academy.

Chapter VIII.

MEETINGS.

1. *Business Meetings.* Business meetings of the Academy shall be held on the first Monday of each month from October to May inclusive.

2. *Sectional Meetings.* Sectional meetings shall be held on Monday evenings from October to May inclusive, and at such other times as the Council may determine. The sectional meeting shall follow the business meeting when both occur on the same evening.

3. *Annual Meeting.* The Annual Meeting shall be held on the third Monday in December.

4. *Special Meetings.* A special meeting may be called by the Council, provided one week's notice be sent to each Active Member and Fellow, stating the object of such meeting.

Chapter IX.

ORDER OF BUSINESS.

1. *Business Meetings.* The following shall be the order of procedure at business meetings:

   1. Minutes of the previous business meeting.
   2. Report of the Council.
   3. Reports of Committees.
   4. Elections.
   5. Other business.

2. *Sectional Meetings.* The following shall be the order of procedure at sectional meetings:

   1. Minutes of the preceding meeting of the section.
   2. Presentation and discussion of papers.
   3. Other scientific business.

3. *Annual Meetings.* The following shall be the order of procedure at Annual Meetings:

   1. Annual reports of the Corresponding Secretary, Recording Secretary, Treasurer, Librarian, and Editor.
   2. Election of Honorary Members, Corresponding Members, and Fellows.
   3. Election of officers for the ensuing year.
   4. Annual address of the retiring President.

Chapter X.

PUBLICATIONS.

1. *Publications.* The established publications of the Academy shall be the *Annals* and the *Memoirs*. They shall be issued by the Editor under the supervision of the Committee on Publications.

2. *Distribution.* One copy of all publications shall be sent to each Patron, Life Member, Active Member and Fellow, *provided*, that upon enquiry by the Editor such Members or Fellows shall signify their desire to receive them.

3. *Publication Fund.* Contributions may be received for the publication fund, and the income thereof shall be applied toward defraying the expenses of the scientific publications of the Academy.

Chapter XI.

GENERAL PROVISIONS.

1. *Debts.* No debts shall be incurred on behalf of the Academy, unless authorized by the Council.

2. *Bills.* All bills submitted to the Council must be certified as to correctness by the officers incurring them.

3. *Investments.* All the permanent funds of the Academy shall be invested in United States or in New York State securities or in first mortgages on real estate, provided they shall not exceed sixty-five per cent. of the value of the property, or in first mortgage bonds of corporations which have paid dividends continuously on their common stock for a period of not less than five years. All income from patron's fees, life membership fees and donor's fees shall be added to the permanent fund.

4. *Expulsion, etc.* Any Member or Fellow may be censured, suspended or expelled, for violation of the Constitution or By-Laws, or for any offence deemed sufficient, by a vote of three fourths of the Members and three fourths of the Fellows present at any business meeting, provided such action shall have been recommended by the Council at a previous business meeting, and also, that one month's notice of such recommendation and of the offence charged shall have been given the Member accused.

5. *Changes in By-Laws.* No alteration shall be made in these By-Laws unless it shall have been submitted publicly in writing at a business meeting, shall have been entered on the Minutes with the names of the Members or Fellows proposing it, and shall be adopted by two-thirds of the Members and Fellows present and voting at a subsequent business meeting.

MEMBERSHIP OF THE
NEW YORK ACADEMY OF SCIENCES.

31 December, 1909.

HONORARY MEMBERS.

Elected.
1887. Alexander Agassiz, Cambridge, Mass.
1898. Arthur Auwers, Berlin, Germany.
1889. Charles Barrois, Lille, France.
1907. William Bateson, Cambridge, England.
1901. Charles Vernon Boys, London, England.
1904. W. C. Brögger, Christiana, Norway.
1887. William Henry Dallinger, London, England.
1899. Sir George Howard Darwin, Cambridge, England.
1876. W. Boyd Dawkins, Manchester, England.
1902 Sir James Dewar, Cambridge, England.
1901. Emil Fischer, Berlin, Germany.
1876. Sir Archibald Geikie, Haslemere, Surrey, England.
1901. James Geikie, Edinburgh, Scotland.
1898. Sir David Gill, London, England.
1909. K. F. Göbel, Munich, Germany.
1889. George Lincoln Goodale, Cambridge, Mass.
1909. Paul von Groth, Munich, Germany.
1894. Ernst Häckel, Jena, Germany.
1899. Julius Hann, Vienna, Austria.
1898. George W. Hill, West Nyack, N. Y.
1907. J. D. Hooker, Kew, England.
1896. Ambrosius A. W. Hubrecht, Utrecht, Netherlands.
1901. William James, Cambridge, Mass.
1896. Felix Klein, Göttingen, Germany.
1909. Alfred Lacroix, Paris, France.
1876. Viktor von Lang, Vienna, Austria.
1898. E. Ray Lankester, London, England.
1880. Sir Norman Lockyer, London, England.
1900. Franz Leydig, Tauber, Germany.

1898. Fridtjof Nansen, Christiana, Norway.
1908. Wilhelm Ostwald, Gross-Bothen, Germany.
1898. Albrecht Penck, Berlin, Germany.
1898. Wilhelm Pfeffer, Leipzig, Germany.
1900. Edward Charles Pickering, Cambridge, Mass.
1900. Jules Henri Poincaré, Paris, France.
1901. Sir William Ramsay, London, England.
1899. Lord Rayleigh, Witham, Essex, England.
1898. Hans H. Reusch, Christiana, Norway.
1887. Sir Henry Enfield Roscoe, London, England.
1887. Heinrich Rosenbusch, Heidelberg, Germany.
1904. Karl von den Steinen, Berlin, Germany.
1904. G. Johnstone Stoney, London, England.
1908. Eduard Strasburger, Bonn, Germany.
1896. Joseph John Thomson, Cambridge, England.
1900. Edward Burnett Tylor, Oxford, England.
1904. Hugo de Vries, Amsterdam, Netherlands.
1907. James Ward, Cambridge, England.
1909. August Weissmann, Freiburg, Germany.
1904. Wilhelm Wundt, Leipzig, Germany.
1904. Ferdinand Zirkel, Leipzig, Germany.

DECEASED HONORARY MEMBERS.

1820. Pedro Abadia, Lima, Peru.
1876. R. Ackermann, Stockholm, Sweden.
1820. C. A. Agardte, Lund, Sweden.
1836. Louis Agassiz, Cambridge, Mass.
1836. George A. Walker Arnott, Kingcross.
1817. Hoffman Bang, Odense, Denmark.
1827. Jöns Jakob Berzelius, Stockholm, Sweden.
1817. Lesueur Bigelow.
1817. Bivona, Palermo, Sicily.
1898. W. K. Brooks, Baltimore, Md.
1897. Robert Brown, London, England.
1828. William Buckland, Oxford, England.
1876. Robert Bunsen, Heidelberg, Germany.
1852. Alph. de Candolle, Geneva, Switzerland.
1817. Augustin Pyrame de Candolle, Montpellier, France.
1876. William P. Carpenter.

1817. H. Casstrom, Stockholm, Sweden.
1883. Michel Eugène Chevreul, Paris, France.
1817. Bracey Clark, London, England.
1819. Parker Cleveland.
1818. DeWitt Clinton, Albany, N. Y.
1819. Jules Cloquet, Paris, France.
1817. Jaccheus Collins, Philadelphia, Pa.
1876. James Croll, Edinburgh, Scotland.
1852. James D. Dana, New Haven, Conn.
1879. Charles Darwin, London, England.
1876. J. W. Dawson, Montreal, Canada.
1830. Count Dejian, Paris, France.
1836. Henry De la Bèche, London, England.
1852. G. P. Deshayes, Paris, France.
1876. Henri St. Clair Deville, Paris, France.
1876. A. Descloiseuux, Paris, France.
1876. Jean Baptiste Dumas, Paris, France.
1817. Adolf Ebeling, Hamburg, Germany.
1876. Philip Egerton, England.
——. Christian Gottfried Ehrenberg, Berlin, Germany.
1817. Stephen Elliot, Charleston, S. C.
1836. Christian G. N. von Esenbeck, Breslau, Germany.
1827. Baron Ferussac, Paris, France.
1852. G. Fischer, Moscow, Russia.
1879. Hoppolyte L. Fizeau, Paris, France.
1887. W. H. Flower, London, England.
1879. Edward Frankland, London, England.
1817. Freehauf, Nazareth, Pa.
1876. Hans Geinitz, Dresden, Germany.
1819. George Gibbs, Newport, R. I.
1889. Wolcott Gibbs, New York, N. Y.
1852. Asa Gray, Cambridge, Mass.
1823. Robert K. Greville, Edinburgh, Scotland.
1836. Gruelin, Tübingen, Germany.
1876. L. Gruner, Paris, France.
1877. Arnold Guyot, Princeton, N. J.
1889. Asaph Hall, Washington, D. C.
1852. James Hall, Albany, N. Y.
1852. William H. Harvey, Dublin, Ireland.
1817. René Just Haüy, Paris, France.
1876. Oswald Heer, Zürich, Germany.

1876. Joseph Henry, Washington, D. C.
1876. A. W. Hofmann, Berlin, Germany.
1852. John E. Holbrook, Charleston, S. C.
1817. Benjamin Homans, Washington, D. C.
1823. William Jackson Hooker, Glasgow, Scotland.
1818. David Hosack, New York, N. Y.
1827. Alexander von Humboldt, Hamburg, Germany.
1891. T. Sterry Hunt, Ottawa, Canada.
1817. Thomas Jefferson, Monticello, Va.
1879. James P. Joule, Sale, Eng., Italy, Australia.
1879. Gustavus Kirchoff, Berlin, Germany.
1817. George Christian Knapp, Halle, Germany.
1879. Nicholas V. Kochscharow, St. Petersburg, Russia.
1817. John Lambert, London, England.
1823. V. F. Lamorous, Caen, France.
1887. S. P. Langley, Washington, D. C.
1827. M. Latreille, Paris, France.
1830. John Lindley, London, England.
1824. John G. C. Lehman, Hamburg, Germany.
1887. Joseph Leidy, Philadelphia, Pa.
1836. Charles Lyell, London, England.
1817. James MacBride, Charleston, S. C.
1821. William McClure, Philadelphia, Pa.
1817. William J. MacNevin.
1876. Clerk Maxwell, Cambridge, Mass.
1888. G. Meneghini, Italy.
1852. H. Milne-Edwards, Paris, France.
1908. Kakichi Mitsukuri Tokio, Japan.
1896. Henri Moissan, Paris, France.
1817. James Monroe, Washington, D. C.
1836. Roderick Impey Murchison, London, England.
1891 Simon Newcomb, Washington, D. C.
1817. Noel, Paris, France.
1817. E. Nott, Schenectady, N. Y.
1879. Richard Owen, London, England.
1817. Charles W. Peale, Philadelphia, Pa.
1879. I. L. A. de Quatrefages, Paris, France.
1882. Henry Creswicke Rawlinson, London, England.
1823. Stephen von Renselaer, Troy, N. Y.
1876. H. F. Richter, Freiburg, Germany.
1900. Henry A. Rowland, Baltimore, Md.

1879. Warren de la Rue, London, England.
1817. Gaetano Savi, Pisa, Italy.
1876. Pietro Angelo Secchi, Rome, Italy.
1817. Correa de Serra.
1819. Benjamin Silliman, New Haven, Conn.
1817. Charles Hamilton Smith, Antwerp, Belgium.
1817. James Edward Smith, London, England.
1817. C. L. Somme, Antwerp, Belgium.
1817. Henry Steinhauer, Bethlehem, Pa.
1889. George G. Stokes, London, England.
1836. Alex. Gregorievitch Strogonoff, St. Petersburg, Russia.
1817. Joseph G. Swift, West Point, N. Y.
1890. Josef Szabó, Buda-Pesth, Hungary.
1828. Thomas Thomson, Glasgow, Scotland.
1836. C. B. Trinius, St. Petersburg, Russia.
1876. P. Ritter von Turner, Scoben.
1887. John Tyndall, London, England.
1836. Achille Valenciennes, Paris, France.
1841. Edouard de Verneuil, Paris, France.
1898. R. Virchow, Berlin, Germany.
1841. Chas. Fred. Philip Von Martins, Münich, Germany.
1887. Ferdinand Von Miller, Melbourne, Australia.
1876. Frederick Wöhler, Göttingen, Germany.
1876. Adolphe Wurtz, Paris, France.
1878. Charles A. Young, Princeton, N. J.
1898. Karl von Zittel, Munich, Germany.

CORRESPONDING MEMBERS.

1883. Charles Conrad Abbott, Trenton, N. J.
1898. Frank D. Adams, Montreal, Canada.
1891. José G. Aguilera, Mexico City, Mexico.
1890. William DeWitt Alexander, Honolulu, Hawaii.
1899. C. W. Andrews, London, England.
1876. John Howard Appleton, Providence, R. I.
1899. J. G. Baker, Kew, England.
1898. Isaac Bagley Balfour, Edinburgh, Scotland.
1878. Alexander Graham Bell, Washington, D. C.
1867. Edward L. Berthoud, Golden, Colo.
1897. Herbert Bolton, Bristol, England.

1899. G. A. Boulenger, London, England.
1874. T. S. Brandegee, San Diego, Calif.
1884. John C. Branner, Stanford University, Calif.
1894. Bohuslay Brauner, Prague, Bohemia.
1874. William Brewster, Cambridge, Mass.
1876. George Jarvis Brush, New Haven, Conn.
1898. T. C. Chamberlin, Chicago, Ill.
1876. Frank Wigglesworth Clarke, Washington, D. C.
1891. L. Clerc, Ekaterinburg, Russia.
1877. Theodore Comstock, Los Angeles, Calif.
1868. M. C. Cooke, London, England.
1876. H. B. Cornwall, Princeton, N. J.
1880. Charles B. Cory, Boston, Mass.
1877. Joseph Crawford, Philadelphia, Pa.
1866. Hermann Credner, Leipzig, Germany.
1895. Henry P. Cushing, Cleveland, O.
1879. T. Nelson Dale, Pittsfield, Mass.
1870. William Healey Dall, Washington, D. C.
1885. Edward Salisbury Dana, New Haven, Conn.
1898. William M. Davis, Cambridge, Mass.
1894. Ruthven Deane, Chicago, Ill.
1899. Charles Déperet, Lyons, France.
1890. Orville A. Derby, Rio Janeiro, Brazil.
1899. Louis Dollo, Brussels, Belgium.
1876. Henry W. Elliott, Lakewood, O.
1880. John B. Elliott, New Orleans, La.
1869. Francis E. Engelhardt, Syracuse, N. Y.
1879. Herman LeRoy Fairchild, Rochester, N. Y.
1879. Friedrich Bernhard Fittica, Marburg, Germany.
1885. Lazarus Fletcher, London, England.
1899. Eberhard Fraas, Stuttgart, Germany.
1879. Reinhold Fritzgartner, Tegucigalpa, Honduras.
1870. Grove K. Gilbert, Washington, D. C.
1858. Theodore Nicholas Gill, Washington, D. C.
1865. Charles A. Goessman, Amherst, Mass.
1888. Frank Austin Gooch, New Haven, Conn.
1868. C. R. Greenleaf, San Francisco, Calif.
1883. Marquis Antonio de Gregorio, Palermo, Sicily.
1869. R. J. Lechmere Guppy, Trinidad, British West Indies.
1898. George E. Hale, Mt. Wilson, Calif.
1882. Baron Ernst von Hesse-Wartegg, Lucerne, Switzerland.

1867. G. H. Hitchcock, Hanover, N. H.
1908. William Henry Holmes, Washington, D. C.
1890. H. D. Hoskold, Buenos Ayres, Argentine Republic.
1896. J. P. Iddings, Chicago, Ill.
1875. Malvern W. Iles, Dubuque, Ia.
1899. Otto Jäckel, Greifswald, Germany.
1876. David Starr Jordan, Stanford University, Calif.
1876. George A. Koenig, Houghton, Mich.
1899. Friedrich Kohlrausch, Marburg, Germany.
1888. Baron R. Kuki, Tokyo, Japan.
1876. John W. Langley, Cleveland, O.
1876. S. A. Lattimore, Rochester, N. Y.
1894. William Libbey, Princeton, N. J.
1899. Archibald Liversidge, London, England.
1876. George Macloskie, Princeton, N. J.
1876. John William Mallet, Charlottesville, Va.
1891. Charles Riborg Mann, Chicago, Ill.
1867. George F. Matthew, St. John, N. B., Canada.
1874. Charles Johnson Maynard, West Newton, Mass.
1874. Theodore Luqueer Mead, Oviedo, Fla.
1888. Seth E. Meek, Chicago, Ill.
1892. J. de Mendizábal-Tamborrel, Mexico City, Mexico.
1874. Clinton Hart Merriam, Washington, D. C.
1898. Mansfield Merriam, South Bethlehem, Pa.
1890. A. B. Meyer, Berlin, Germany.
1878. Charles Sedgwick Minot, Boston, Mass.
1876. William Gilbert Mixter, New Haven, Conn.
1890. Richard Moldenke, Watchung, N. J.
1895. C. Lloyd Morgan, Bristol, England.
1864. Edward S. Morse, Salem, Mass.
1898. George Murray, London, England.
——. Eugen Netto, Giessen, Germany.
1866. Alfred Newton, Cambridge, England.
1897. Francis C. Nicholas, New York, N. Y.
1882. Henry Alfred Alford Nicholls, Dominica, B. W. I.
1881. William H. Niles, Boston, Mass.
1880. Edward J. Nolan, Philadelphia, Pa.
1879. Frederick A. Ober, Hackensack, N. J.
1876. John M. Ordway, New Orleans, La.
1900. George Howard Parker, Cambridge, Mass.
1876. Stephen F. Peckham, New York, N. Y.

1888. George E. Post, Beirût, Syria.
1894. Edward Bagnall Poulton, Oxford, England.
1877. Frederick Prime, Philadelphia, Pa.
1868. Raphael Pumpelly, Newport, R. I.
1876. B. Alex. Randall, Philadelphia, Pa.
1876. Ira Remsen, Baltimore, Md.
1874. Robert Ridgway, Washington, D. C.
1886. William L. Robb, Troy, N. Y.
1876. Samuel P. Sadtler, Philadelphia, Pa.
1899. D. Max Schlosser, Munich, Germany.
1867. Paul Schweitzer, Columbia, Mo.
1898. W. B. Scott, Princeton, N. J.
1876. Samuel H. Scudder, Cambridge, Mass.
1894. W. T. Sedgwick, Boston, Mass.
1876. Andrew Sherwood, Portland, Ore.
1883. J. Ward Smith, Newark, N. J.
1895. Charles H. Smyth, Jr., Princeton, N. J.
1890. J. Selden Spencer, Tarrytown, N. Y.
1896. Robert Stearns, Los Angeles, Calif.
1890. Walter LeConte Stevens, Lexington, Va.
1876. Francis H. Storer, Boston, Mass.
1885. Rajah Sourindro Mohun Tagore, Calcutta, India.
1893. J. P. Thomson, Brisbane, Queensland, Australia.
1899. R. H. Traquair, Colinton, Scotland.
1877. John Trowbridge, Cambridge, Mass.
1876. D. K. Tuttle, Philadelphia, Pa.
1871. Henri Van Heurck, Antwerp, Belgium.
1900. Charles R. Van Hise, Madison, Wis.
1867. Addison Emery Verrill, New Haven, Conn.
1890. Anthony Wayne Vogdes, San Diego, Calif.
1898. Charles Doolittle Walcott, Washington, D. C.
1876. Leonard Waldo, New York, N. Y.
1900. Sho Watasé, Tokyo, Japan.
1897. Stuart Weller, Chicago, Ill.
1874. I. C. White, Morgantown, W. Va.
1898. C. O. Whitman, Woods Holl, Mass.
1898. Henry Shaler Williams, Ithaca, N. Y.
1898. N. H. Winchell, Minneapolis, Minn.
1866. Horatio C. Wood, Philadelphia, Pa.
1899. A. Smith Woodward, London, England.
1876. Arthur Williams Wright, New Haven, Conn.
1876. Harry Crècy Yarrow, Washington, D. C.

PATRONS.

BRITTON, Prof. N. L., N. Y. Botanical Garden.
BROWN, Hon. ADDISON, 45 West 89th Street.
CASEY, Col. THOMAS L., U. S. A., Washington, D. C.
CHAPIN, CHESTER W., 331 West End Ave.
FIELD, C. DE PEYSTER, 21 East 26th Street.
GOULD, EDWIN, Dobbs Ferry, N. Y.
GOULD, GEORGE J., 195 Broadway.
GOULD, Miss HELEN M., Irvington, N. Y.
HERRMAN, Mrs. ESTHER, 59 West 56th Street.
JULIEN, Dr. ALEXIS A., Columbia University.
LEVISON, W. GOOLD, 1435 Pacific Street, Brooklyn.
MEAD, WALTER H., 67 Wall Street.
SENFF, CHARLES H., 300 Madison Avenue.

ACTIVE MEMBERS.

31 DECEMBER, 1909.

Fellowship is indicated by an asterisk (*) before the name. Life Membership is shown by heavy-faced type. The names of Patrons are in capitals.

Adams, Edward D.
*ALLEN, J. A., Ph.D.
ALLEN, JAMES LANE
***Allis, Edward Phelps, Jr., Ph.D.**
*AMEND, BERNARD G.
ANDERSON, A. A.
ANDERSON, A. J. C.
*ANDREWS, ROY C.
Anthony, R. A.
AREND, FRANCIS J.
Armstrong, S. T., M.D.
ARNOLD, FELIX, M.D.
ASTOR, JOHN JACOB
AVERY, SAMUEL P.
BAEKELAND, LEO H., Ph.D.
Bailey, James M.
Barhydt, Mrs. P. H.
BARNES, Miss CORA F.
BARRON, GEORGE D.
*BASKERVILLE, Prof. CHARLES
BAUGH, Miss M. L.
BAXTER, M., Jr.
BEAL, WILLIAM R.
BEAN, HENRY WILLARD

BEARD, DANIEL C.
***Beck, Fanning C. T.**
*BEEBE, C. WILLIAM
BEERS, M. H.
BELLER, A.
BERGSTRESSER, CHARLES M.
*BERKEY, CHARLES P., Ph.D.
*BERRY, EDWARD W.
BETTS, SAMUEL R.
VAN BEUREN, F. T.
*BICKMORE, ALBERT S., Ph.D.
*BIGELOW, Prof. MAURICE A., Ph.D.
BIGELOW, WILLIAM S.
BIJUR, MOSES
Billings, Miss Elizabeth
BIRDSALL, Mrs. W. R.
BIRKHAHN, R. C.
BISHOP, HEBER R.
BISHOP, SAMUEL H.
*BLAKE, J. A., M.D.
BLANK, M. I., M.D.
***Bliss, Prof. Charles B.**
*BOAS, Prof. FRANZ
BOETTGER, HENRY W.
BÖHLER, RICHARD F.
BOYD, JAMES
*BRISTOL, Prof. CHARLES L.
BRISTOL, JNO. I. D.
*BRITTON, PROF. N. L., PH.D.
*BROWN, HON. ADDISON
BROWN, EDWIN H.
BROWN, T. QUINCY
*BROWNELL, SILAS B.
*BUMPUS, Prof. H. C., Ph.D.
BURR, WINTHROP
BUSH, WENDELL T.
*BYRNES, Miss ESTHER P., Ph.D.
*CALKINS, Prof. GARY N., Ph.D.
*CAMPBELL, Prof. WILLIAM, Ph.D.
*CAMPBELL, Prof. WILLIAM M.
CANFIELD, R. A.
CARLEBACH, WALTER MAXWELL
*CASEY, COL. T. L., U. S. A.
***Cattell, Prof. J. McKeen, Ph.D.**
CHAMPOLLION, ANDRÉ
*CHANDLER, Prof. C. F., Ph.D.
CHAPIN, CHESTER W.
*CHAPMAN, FRANK M.
*CHEESMAN, TIMOTHY M., M.D.
CLARKSON, BANYER
CLINE, Miss MAY
COHN, JULIUS M.
*COLLINGWOOD, FRANCIS
Collord, George W.
COMBE, Mrs. WILLIAM
Constant, S. Victor
DE COPPET, E. J.
CORNING, CHRISTOPHER R.
*COX, CHARLES F.
*CRAMPTON, Prof. HENRY E., Ph.D.
Crane, Zenas
DAHLGREN, B. E., D.M.D.
*DAVENPORT, Prof. C. B., Ph.D.
DAVIES, J. CLARENCE
DAVIES, WILLIAM G.
DAVIS, Dr. CHARLES H.
***Dean, Prof. Bashford, Ph.D.**
Delafield, Maturin L., Jr.
DELANO, WARREN, Jr.
DEMOREST, WILLIAM C.
DEVEREUX, W. B.
DEWITT, WILLIAM G.
DICKERSON, EDWARD N.
DIEFENTHÄLER, C. E.
DIMOCK, GEORGE E.
DODGE, Rev. D. STUART, D.D.
Dodge, Miss Grace H.
*DODGE, Prof. RICHARD E., A.M.
DOHERTY, HENRY L.
DONALD, JAMES M.
*DOREMUS, Prof. CHARLES A., Ph.D.
***Douglas, James**

DOUGLASS, ALFRED
DRAPER, MRS. M. A. P.
DRUMMOND, ISAAC W., M.D.
*DUDLEY, P. H., Ph.D.
*DUNHAM, EDWARD K., M.D.
Dunn, Gano
Dunscombe, George Elsworth
*DUTCHER, WILLIAM
*DWIGHT, JONATHAN, Jr., M.D.
DWYER, THOMAS
EICKEMEYER, CARL
***Elliott, Prof. A. H., Ph.D.**
EMMETT, C. TEMPLE
ENO, JOHN C.
ENO, WILLIAM PHELPS
ESTABROOK, A. F.
*EYERMAN, JOHN
FAIRCHILD, CHARLES S.
FALLON, G. W. R.
FARGO, JAMES C.
FARMER, ALEXANDER S.
*FARRAND, Prof. LIVINGSTON, M. D.
FERGUSON, MRS. JULIANA ARMOUR
FIELD, C. DE PEYSTER
FIELD, WILLIAM B. OSGOOD
*FINLEY, Pres. JOHN H.
*FISHBERG, MAURICE, M.D.
*FLEXNER, SIMON, M.D.
FOOT, JAMES D.
Ford, James B.
FORDYCE, JOHN A.
DE FOREST, ROBERT W.
FORSTER, WILLIAM
FREUND, EMIL
FRISSELL, A. S.
GALLATIN, FREDERIC
GIBSON, R. W.
*GIES, Prof. WILLIAM J.
*GIRTY, GEORGE H.
GOULD, EDWIN
GOULD, GEORGE J.
GOULD, MISS HELEN M.
***Grabau, Prof. Amadeus W.**
*GRATACAP, LOUIS P.
*GREGORY, W. K.
GRIGGS, GEORGE
GRISCOM, C. A., Jr.
GRISWOLD, MRS. CHESTER
GUGGENHEIM, WILLIAM
VON HAGEN, HUGO
HALLS, WILLIAM, Jr.
HAMMOND, JAMES B.
HAUPT, LOUIS, M.D.
HAVEMEYER, WILLIAM F.
HEINZE, ARTHUR P.
*HERING, Prof. DANIEL W.
HERRMAN, MRS. ESTHER
*HERTER, CHRISTIAN A., M.D.
HESS, SELMAR
HEWLETT, WALTER J.
HIGGINSON, JAMES J.
*HILL, ROBERT T.
HIRSCH, CHARLES S.
*HITCHCOCK, Miss F. R. M., Ph.D.
HODENPYL, ANTON G.
*HOLLICK, ARTHUR, Ph.D.
Holt, Henry
Hopkins, George B.
*HORNADAY, WILLIAM T., Sc.D.
HOTCHKISS, HENRY D.
HOUSE, Prof. HOMER D.
***Hovey, Edmund Otis, Ph.D.**
*HOWE, Prof. HENRY M.
*HOWE, MARSHALL A., Ph.D.
Hubbard, Thomas H.
HUBBARD, WALTER C.
HUGHES, HON. CHARLES E.
Huntington, Archer M.
*HUSSAKOF, LOUIS
HUSTACE, FRANCIS
HUYLER, JOHN S.
Hyde, B. Talbot B.

HYDE, E. FRANCIS
Hyde, Frederic E., M.D.
HYDE, HENRY ST. JOHN
Iles, George
*IRVING, Prof. JOHN D.
IRVING, WALTER
VON ISAKOVICS, ALOIS
*JACOBI, ABRAM, M.D.
Jarvie, James N.
JENNINGS, ROBERT E.
JONES, DWIGHT A.
*JULIEN, ALEXIS A., Ph.D.
KAHN, OTTO H.
***Kemp, Prof. James F., A.B., E.M.**
Keppler, Rudolph
Kessler, George A.
KOHLMAN, CHARLES
*KUNZ, GEORGE F., M.A., Ph.D.
Lamb, Osborn R.
LAMBERT, ADRIAN V. S., M.D.
LANGDON, WOODBURY G.
LANGELOTH, J.
*LANGMANN, GUSTAV, M.D.
LAWRENCE, AMOS E.
LAWRENCE, JOHN B.
Lawton, James M.
*LEDOUX, ALBERT R., Ph.D.
*LEE, Prof. FREDERIC S., Ph.D.
*LEVISON, WALLACE GOOLD
LEVY, EMANUEL
LICHTENSTEIN, PAUL
LIEB, J. W., Jr.
*LINVILLE, H. R., Ph.D.
Loeb, James
*LOEB, Prof. MORRIS, Ph.D.
LOUNSBERY, R. P.
Low, Hon. Seth, LL.D.
LOWIE, ROBERT H., Ph.D.
*LUCAS, F. A.
*LUQUER, Prof. LEA McI.
*LUSK, Prof. GRAHAM, M.D.
LYON, RALPH
McCook, Col. J. J.
***McMillin, Emerson**
MACARTHUR, ARTHUR F.
*MACDOUGALL, Prof. ROBERT
MACY, Miss MARY SUTTON, M.D.
Macy, V. Everit
MAGER, F. ROBERT
MANN, W. D.
MARBLE, MANTON
MARCOU, JOHN B.
MARLING, ALFRED E.
Marshall, Louis
MARSTON, E. S.
Martin, Bradley
***Martin, Prof. Daniel S.**
*MARTIN, T. COMMERFORD
***Matthew, W. D., Ph.D.**
MAXWELL, FRANCIS T.
MEAD, WALTER H.
MEIGS, TITUS B.
MELLEN, C. S.
*MELTZER, S. J., M.D.
*MERRILL, FREDERICK J. H., Ph.D.
METZ, HERMAN A.
*MEYER, ADOLF, M.D.
MILBURN, J. G.
DE MILHAU, LOUIS J.
MILLER, GEORGE N., M.D.
***Miner, Roy Waldo**
MITCHELL, ARTHUR M.
MOREWOOD, GEORGE B.
MORGAN, J. PIERPONT
*MORGAN, Prof. THOMAS H.
MORRIS, LEWIS R., M.D.
MYERS, JOSEPH G.
Nimick, Mrs. A. K.
OAKES, FRANCIS J.
OCHS, ADOLPH S.
OETTINGER, P. J., M.D.
***Ogilvie, Miss Ida H., Ph.D.**

Olcott, E. E.
OLMSTED, Mrs. CHARLES T.
***Osborn, Prof. H. F., Sc. D., LL.D.**
OSBORN, WILLIAM C.
OSBURN, RAYMOND C.
Owen, Miss Juliette A.
OWENS, W. W.
PADDOCK, EUGENE H.
Parish, Henry
*PARKER, Prof. HERSCHEL C.
PARSONS, Mrs. EDWIN
*PARSONS, JOHN E.
Patton, John
PEDERSEN, F. M.
*PELLEW, Prof. C. E., Ph.D.
PENNINGTON, WILLIAM
Perkins, William H.
PERRY, CHARLES J.
*PETERSON, FREDERICK, M.D.
*PETRUNKEVITCH, ALEXANDER, Ph.D.
PETTEGREW, DAVID L.
PFIZER, CHARLES, Jr.
PHILIPP, P. BERNARD
PHIPPS, HENRY
PHOENIX, LLOYD
PICKHARDT, CARL
PIERCE, HENRY CLAY
*PITKIN, LUCIUS, Ph.D.
PLANTEN, JOHN R.
*POLLARD, CHARLES L., Ph. D.
*POOR, Prof. CHARLES L.
PORTER, EUGENE H.
POST, ABRAM S.
*POST, C. A.
*POST, GEORGE B.
*PRINCE, Prof. JOHN DYNELEY
PRITCHETT, Pres. HENRY S.
PROCTER, WILLIAM
PROCTOR, GEORGE H.
*PUPIN, Prof. M. I., Ph.D.
Pyne, M. Taylor
QUACKENBOS, Prof. J. D., M.D.
REILLY, F. JAMES
RICHARDSON, FREDERICK A.
***Ricketts, Prof. P. de P., Ph.D.**
RIEDERER, LUDWIG
RIKER, SAMUEL
ROBB, Hon. J. HAMPDEN
ROBERT, SAMUEL
ROBERTS, C. H.
ROGERS, E. L.
de Rubio, H. A. C.
*RUSBY, Prof. HENRY H., M.D.
RUSS, EDWARD
SACHS, PAUL J.
SAUL, CHARLES R.
SAUTER, FRED.
Schermerhorn, F. A.
SCHIFF, JACOB H.
SCHOLLE, A. H.
Schott, Charles M., Jr.
SCOTT, GEORGE S.
SENFF, CHARLES H.
SHAW, Mrs. JOHN C.
SHEPARD, C. SIDNEY
*SHERWOOD, GEORGE H.
SHULTZ, CHARLES S.
*SICKELS, IVIN, M.D.
SIEBERG, W. H. J.
SLOAN, BENSON B
SMITH, ELLIOTT C.
*SMITH, ERNEST E., M.D., Ph.D.
*SMITH, Prof. JOHN B.
SNOW, ELBRIDGE G.
SQUIBB, EDWARD H.
*STARR, Prof. M. ALLEN
STEFÁNSSON, V.
Stetson, F. L.
STEVENS, C. AMORY
*STEVENS, GEORGE T., M.D.
***Stevenson, Prof. John J., LL.D.**

Stokes, James
Stokes, J. G. Phelps
Straus, Isidor
Sturgis, Mrs. Elizabeth M.
*Stuyvesant, Rutherfurd
Taggart, Rush
***Tatlock, John, Jr.**
Taylor, George
Taylor, William H.
Terry, James
Tesla, Nikola
Thatcher, Edward J., Jr.
Thaw, Benjamin
Thompson, Mrs. Frederick F.
Thompson, Lewis S.
*Thompson, Prof. W. Gilman
Thompson, Walter
*Thorndike, Prof. Edward L.
Thorne, Samuel
*Tower, R. W., Ph.D.
*Townsend, Charles H.
Tows, C. D.
*Trowbridge, Prof. C. C.
Tuckerman, Alfred, Ph.D.
Ullmann, E. S.
Van Slyck, George W.
Van Wyck, Robert A.
***Waller, Prof. Elwyn, Ph.D.**
Warburg, F. N.
Warburg, Paul M.
Ward, Artemas
Ward, John Gilbert
Warner, Charles St. John
Warren, Charles Elliott
*Washington, Henry S., Ph.D.
Waterbury, J. I.
Weir, Col. John
Wellington, Aaron H.
Wheeler, H. L.
*White, Horace
***Whitfield, Prof. R. P.**
Wicke, William
Wiggin, F. H., M.D.
Williams, R. H.
Wills, Charles T.
*Wilson, Prof. E. B., Ph.D., LL.D.
Wilson, Henry R.
Wilson, J. H.
Wilson, Miss M. B., M.D.
*Wissler, Clark, Ph.D.
Wood, Mrs. Cynthia A.
*Woodbridge, Prof. F. J. E.
*Woodhull, Prof. John F., Ph.D.
Woodman, Prof. J. Edmund
*Woodward, Prof. R. S.
*Woodworth, Prof. R. S.
Younglove, John, M.D.
Zabriskie, George

ASSOCIATE MEMBERS.

Billingsley, Paul
Brown, Harold Chapman, Ph.D.
Brown, T. C.
Byrne, Joseph P.
Dublin, L. J.
Fenner, Clarence N.
Gordon, Clarence E.
Hunter, George H.
James, F. Wilton
Johnson, Julius M.
Kellicott, W. E., Ph.D.
McGregor, James Howard
Montague, W. P., Ph.D.
Northup, Dwight
Rogers, G. Sherbourne
Stevenson, A. E.
Wood, Miss Elvira
Ziegler, Victor

NON-RESIDENT MEMBERS.

*Abbe, Dr. Cleveland
Buchner, Edward F.
Burnett, Douglass
Davis, William H.
English, George L.
Finlay, Prof. G. I.
Frankland, Frederick W.
Hoffman, S. V.
Kenning, Amos B.
*Lloyd, Prof. F. E.
*Mayer, Dr. A. G.
*Pratt, Dr. J. H.
*Ries, Prof. H.
Reuter, L. H.
*Sumner, Dr. F. B.
*van Ingen, Prof. G.
*Wheeler, Wm. Morton

GENERAL INDEX TO VOLUME XIX.

Names of Authors and other Persons in **Heavy-Face Type**.

Titles of Papers in SMALL CAPS.

INDEX

18